Concise Explanatory Statement (RCW 34.05.325.6a)
WAC 296-62-051, Ergonomics

> "As the Director of the National Institute for Occupational Safety and Health (NIOSH), I am very pleased to provide testimony on the topic of workplace hazards and work-related musculoskeletal disorders (MSDs). It may surprise you that the Director of a Federal agency is testifying on the State of Washington Proposed Ergonomics Rule. However, this is an important issue that affects the lives of millions of workers and their families in every state. Much of the important work in addressing this national problem is happening at the state level…NIOSH is a public health research institute within the Centers for Disease Control and Prevention, a part of the Department of Health and Human Services. NIOSH is the only federal agency mandated to conduct research and train professionals to prevent workplace hazards…Although nonoccupational factors can contribute to the development and exacerbation of these disorders, during our 29 years of existence, NIOSH has amassed research and experience that establishes a clear relationship between workplace hazards and MSDs. We believe, therefore, that there is an adequate science base to initiate rulemaking for an ergonomics standard. What Washington State has proposed – a standard to identify workplace hazards, complete hazard analysis, and address and reduce these hazards -– is strongly rooted in this science base. The Proposed Ergonomics Rule, in fact, proposes scientifically valid and feasible recommendations, which, if more widely implemented, will reduce the economic and human burden of the largest occupational health problem in your state…
>
> The bottom line is that we know enough now to prevent or reduce the severity of many of these disorders, and the Washington State Proposed Ergonomics rule is an effective and scientifically valid way to do so."
>
> Linda Rosenstock, MD, MPH (testimony[1])

THE RULE IS BASED ON WELL-SETTLED LEGAL PRINCIPLES.

The Washington State Department of Labor and Industries (L&I) has adopted this workplace ergonomics rule to establish requirements for employers to identify workplace hazards that cause work-related musculoskeletal disorders (WMSDs)[2] and to reduce employee exposure below hazardous levels or to the extent feasible. Ergonomics is the science and the practice of designing jobs or workplaces to match the capabilities and limitations of the human body. WMSDs are work-related non-traumatic disorders involving soft tissues such as muscles, tendons, ligaments, joints, blood vessels and nerves (e.g. carpal tunnel syndrome and tendinitis).

RCW 49.17.020(6) requires that standards be "reasonably necessary or appropriate." Additionally, RCW 49.17.050(4) provides that standards shall be based on "the best available evidence" and will assure "to the extent feasible…that no employee will suffer material impairment of health or functional capacity even if such employee has regular exposure to the hazard dealt with by such standard for the period of his working life…"

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[1] Throughout this document the term "testimony" refers to statements prepared for the public hearings on this rule held between 1/5/2000 and 1/14/2000. The term "comments" refers to written, post hearing submissions to the rulemaking record.

[2] Unless otherwise noted, references in this document to work-related musculoskeletal disorders (or WMSDs) mean work-related non-traumatic soft tissue disorders such as carpal tunnel syndrome and tendinitis and exclude injuries from slips, trips, falls, motor vehicle accidents or being struck by or caught in objects. "Non-traumatic soft tissue disorders" are fully defined in Silverstein, Viikari-Juntura and Kalat 2000. The statistics in that report are for the neck, back and upper extremity, but not the lower extremity, thereby underestimating the total impact of WMSDs.

L&I relied on several key legal concepts to develop this rule. First, the WISHA statute directs L&I to rely upon the best available evidence to demonstrate that workplace hazards causing WMSDs pose a material impairment to the health and functional capacity of workers. A substantial body of epidemiological and other scientific evidence, considered as a whole, demonstrates a causal relationship between certain physical risk factors at work and painful, disabling WMSDs. Individual studies that are not consistent with this conclusion are not sufficient to undermine it.

Second, the rule must be reasonably necessary and appropriate to prevent exposures to physical risk factors associated with an increased incidence of WMSDs. WMSDs are sufficiently frequent, severe, and widespread among the Washington State workforce that preventive regulation is necessary. Further, the prevalence and severity of WMSDs increases with increased intensity, frequency and duration of exposure to physical risk factors. Therefore, a rule requiring reductions in such exposures will reduce the incidence of WMSDs. Voluntary, non-regulatory efforts to reduce WMSDs have been useful and necessary, but not sufficient.

L&I designed this rule so it regulates only the work contribution of certain physical risk factors to WMSD incidence. L&I recognizes that some employees encounter these risk factors outside of work. This rule is limited to reducing job hazards. It will reduce the incidence of WMSDs but it does not guarantee that no injuries will occur. It ensures that employers must abate only harmful workplace exposures.

Finally, the rule must be technologically and economically feasible for affected industries. The technology to reduce the regulated physical risk factors is widely available and readily affordable. The benefits of reducing employee exposure to the physical risk factors associated with WMSDs outweigh the costs of implementing this rule.

Best Available Evidence

Regulatory agencies are sometimes able to make public policy decisions based upon readily observable and uncontestable facts without the need for scientific induction or deduction. For example, unguarded power saws present workplace hazards that are sufficiently obvious to warrant protective rules without extensive scientific study. However, for many workplace hazards the connection between initial exposure and eventual adverse outcome is less apparent. Lung cancer caused by asbestos typically does not appear for many years after the initial exposure. Carpal tunnel syndrome caused by the cumulative stress of moving the wrist repetitively and forcefully in awkward postures may appear gradually, without being attributable to any specific harmful event. When faced with such health effects that have a gradual or chronic onset or that result from gradual or chronic exposures, regulatory agencies cannot rely on common sense or short-term observation but must use scientific methods to reach conclusions about cause and effect.

Epidemiology is the science that studies the incidence and distribution of diseases or injuries in populations rather than individuals. Its conclusions depend on statistical associations between exposure and outcome. For example, if 70% of workers exposed to chemical X develop disease Y, but only 10% of workers not exposed to the chemical develop the disease (and other possible explanatory factors have been taken into account) it is statistically very likely that chemical X causes disease Y. But, no matter how strong and convincing the association between exposure and outcome, this conclusion about cause and effect is not certain, only statistically likely. It is this lack of absolute certainty in spite of a very high statistical likelihood, for example, that led some to argue that the hazards of cigarette smoking had not been proven -- and to continue this argument long after the scientific community and the Surgeon General had concluded that the evidence was compelling and the risks were clear.

Epidemiology provides a preferred body of scientific information for occupational safety and health decision making because the data derives from real workplace circumstances and does not require extrapolation from laboratory to workplace or from animals to humans. When epidemiological data is not available or sufficient, laboratory or experimental studies on human subjects or animals may provide adequate or supportive information for decision making.

If epidemiology's strengths derive from direct observation in human working populations rather than laboratory subjects, its limitations have the same source. Workplaces are not controlled environments and it is always difficult and frequently impossible to take into account all the variables that can affect the outcome of a study. Scientists therefore do not typically reach conclusions based on a single positive study but seek to replicate findings in a variety of different settings and conditions. Similarly, when conclusions are drawn from a body of studies scientists do not typically reject these conclusions based on a single negative study. The more supporting evidence, the stronger the conclusion that an exposure can cause harm.

The process of drawing conclusions from scientific evidence always involves some degree of uncertainty. This uncertainty has two sources. First, observational or experimental studies provide statistical evidence and inferences based on this evidence. Second, the scientific process requires making general conclusions based upon specific results. Full consensus among scientists is not only rare, but also unexpected.[3] The relevant question for regulatory agencies is not whether a body of science is definitive and unchallenged, but whether it is sufficiently reliable and consistent to serve as the basis for public policy.

Recognizing the limitations of the data available to support regulation of safety and health risks, Congress and the Washington legislature directed that they be regulated on the basis of the "best available evidence."[4] Where scientific or other technical information "is on the frontiers of scientific knowledge" and "the factual finger points, but does not conclude" it "remains the duty of the [agency] to act to protect the workingman, and to act even in circumstances where existing methodology or research is deficient."[5] The "best available evidence" standard suggests that

[3] "By and large, the controversies that we observed reflect the usual disputatiousness of science, which advances when speculative challenges lead to new and clarifying results." Work-Related Musculoskeletal Disorders, National Research Council, 1999, p. 28.

[4] L&I's legal analysis relies, where applicable, on case law interpreting the Occupational Safety and Health Act, whose provisions are nearly identical to those of the Washington Industrial Safety and Health Act. L&I views the legal burdens placed upon it to be similar to those placed on OSHA, except insofar as the Washington State courts have ruled otherwise (e.g. *Aviation West*). References to OSHA's legal obligations are matched by similar obligations for L&I.

[5] *The Society of Plastics Industries v. OSHA*, 509 F.2d 1301 (2d Cir. 1975).

safety and health regulation is appropriate where the Agency "can make reasonable predictions on the basis of credible sources of information." [6]

Criticism of this rule because individual scientific studies have methodological weaknesses or fail to prove a relationship between WMSDs and physical risk factors "fundamentally misconstrues" the role of regulatory agencies because it ignores "the marginal contribution that each piece of evidence makes to the total picture.[7] While some studies may have limitations or inconsistencies, "such incomplete proof is inevitable when the Agency regulates on the frontiers of scientific knowledge."[8] When faced with cumulative evidence: "[OSHA] need not seek a single dispositive study that fully supports [its] determination. Science does not work that way… Rather, [OSHA's] decision may be fully supportable if it is based, as it is, on the inconclusive but suggestive results of numerous studies. By its nature, scientific evidence is cumulative: the more supporting, albeit inconclusive, evidence available, the more likely the accuracy of the conclusion..."[9]

Nor is it appropriate to delay regulation until a scientific consensus emerges on the causes of WMSDs. Congress and the Washington legislature adopted the "best available evidence" standard so regulation of workplace risks would not have to await scientific consensus. Congress did not want OSHA to "be paralyzed by debate within the scientific community."[10] Congress feared OSHA regulation dependent on consensus within the scientific community would represent "the lowest common denominator of acceptance by interested private groups."[11]

The ergonomics standard rests on the cumulative body of epidemiological evidence, case studies and laboratory science about MSDs. Each of the specific physical risk factors covered by this rule are causally related to increased incidence of WMSDs and are commonly encountered at work. There is a strong body of evidence supporting the ergonomics rule. Yet, no one study conclusively establishes the link between WMSDs and these risk factors and some studies suggest such a link does not exist. However, neither the methodological limits of individual studies nor their inconclusive results detract from the overall finding of harm. In this regard, the conclusion that WMSDs are causally linked to each of the physical risk factors covered by this rule is consistent with the conclusions of comprehensive reviews of the scientific literature completed by the National Institute for Occupational Safety and Health (NIOSH) and the National Academy of Science (NAS).

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[6] *United Steelworkers of America v. Marshall*, 647 F.2d at 1266. If OSHA were required to delay regulation until a scientific consensus was achieved, significant harm to workers from latent hazards already would have occurred. Cf. *Industrial Union Department v. American Petroleum Inst.*, 448 U.S. 607 (1980) (noting that OSHA regulation need not wait until deaths have occurred).

[7] *Public Citizen v. Tyson*, 796 F.2d 1479 (D.C. Cir. 1986).

[8] *Id*.

[9] *Id*. quoting *Ethyl Corp. v. EPA*.

[10] Occupational Safety and Health Act Legislative History at 848.

[11] Occupational Safety and Health Act Legislative History at 146.

Health Effects

L&I is authorized and directed to regulate "material impairments to worker health and functional capacity." WMSDs, which may cause severe pain and disability, are a material impairment. WMSDs represent a continuum of health effects, ranging from reversible, minor, subjective symptoms to irreversible, crippling, objectively verifiable conditions. L&I is not required to wait for the most serious outcomes before regulating. It may take action aimed at early, reversible and less severe effects to prevent the most serious, permanent and disabling.[12]

Safety and health standards must be reasonably addressed toward a widespread workplace hazard and be effective at reducing exposure to that hazard. A plurality of the U.S. Supreme Court, in the *Benzene* decision, interpreted the Occupational Safety and Health Act of 1970 to require OSHA to make a threshold finding that a significant risk of harm exists in the workplace before it regulates.[13] Once OSHA finds such a risk of harm, its rule must be "reasonably necessary and appropriate" to reduce that harm.

The Washington Supreme Court has questioned the application of the "significant risk" test articulated in *Benzene*. In *Aviation West et al. V. Labor and Industries*,[14] the State Supreme Court upheld rules enacted under the WISHAct regulating environmental tobacco smoke. The court rejected a strict reading of the plurality opinion advocated by the tobacco companies. Instead, the court adopted Justice Marshall's dissent, which gave OSHA broad discretion in enacting rules provided that they are "reasonably necessary or appropriate."

Aviation West requires a finding that: (1) the hazard the rule proposes to regulate is a sufficiently widespread or severe workplace risk to warrant government intervention; and (2) the rule will be effective at reducing or eliminating exposure to the hazard. The ergonomics rule meets this test, fulfilling the legal obligation defined in *Aviation West*. In fact, the evidence supporting this rule is strong enough to meet even the more stringent reading of the Benzene decision advocated by the tobacco industry in *Aviation West*. Workers' compensation and other data show WMSDs constitute a very substantial workplace risk facing Washington workers. Clearly, workers should be protected from this larger than average risk.[15] The risk to workers rises with increased exposure to each of the physical risk factors regulated by this rule; therefore, reductions in exposure to these risk factors will reduce the risk.[16]

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[12] See *United Steelworkers of America v Marshall; AFL-CIO v Marshall, (DC Cir 1979), aff'd American Textile Mfrs Inst v Donovan (1981)*

[13] *Industrial Union v American Petrol. Inst., 448 US 607, 65 L Ed 2d 1010, 100 S Ct 2844. Benzene* was decided by a majority of 5 to 4, however as pointed out in *Aviation West* Justice Rehnquist concurred in the result only and therefore the significant risk test established by the decision was supported by a plurality. "Quite contrary to the Companies' assertion, it appears that a majority of the Court has never adopted this test, but has instead merely noted that OSHA itself has adopted it."

[14] *Aviation West et al. v. Labor and Industries, 138 Wn.2d 413, 980 P.2d 701 (1999).*

[15] Past OSHA standards have interpreted the *Benzene* decision to permit it to regulate risks of average or above average magnitude. See e.g., 56 Fed. Reg. 64036/1 (December 6, 1991 (Bloodborne Pathogen Standard); 52 Fed Reg 46233 (Dec. 4, 1987)

[16] National Grain and Feed Association. V. OSHA, 866 F2d 717 (5th Cir. 1989).

Critics of the ergonomics rule contend that L&I should not regulate when both workplace and non-workplace factors contribute to MSDs and scientific data is too imprecise to apportion the relative contribution of each. To the contrary, the ergonomics rule is structured so employers are responsible only for reducing hazardous workplace exposures that contribute to WMSDs. While non-workplace exposures to the risk factors covered by the rule do occur, the rule does not regulate these non-workplace exposures and employers are not held accountable for their effects. This rule does not make employers guarantors that employees will never suffer a MSD. By design the ergonomics rule has created an objective workplace measure of compliance to guide industry and to facilitate fair enforcement.[17]

So long as a WISHA regulation addresses workplace harms, and limits employer abatement to workplace conditions, intervention is proper. The leading case is Forging Industries Association v. Secretary of Labor, a challenge to OSHA's hearing conservation standard where the court rejected industry's argument that OSHA exceeded its authority by regulating hearing loss -- an effect that can be caused by aging and exposures outside the workplace.[18] The court upheld the standard because it "ensure[d] that a hearing endangered worker is provided with protection in the workplace in order to decrease the risk of a hearing impairment. Having identified employee susceptibility to noise the Act does not wait for an employee to become injured. It authorizes the promulgation of health and safety standards in the hope that these will act to prevent injuries from occurring."[19] Exposure to environmental tobacco smoke (ETS) posed the same concern. Before L&I promulgated its ETS standard, employees in office environments might be exposed to ETS at work and outside of work. Both exposures contribute to lung cancer. Reducing workplace exposures does not completely eliminate the risk of lung cancer if an employee's non-work exposures continue. Nevertheless, regulation of workplace ETS regulation has been upheld.). Even in situations where there is a synergistic relationship between work and non-work exposures (e.g. asbestos and tobacco smoke), the agency still has good reason and a duty to regulate the workplace contribution to risk.

Feasibility

WISHA rules must be feasible. Feasibility has two elements: the technological ability of affected firms to reduce hazardous exposures and the financial ability of the affected industry to absorb the costs of such controls.

A standard is technologically feasible if L&I, like OSHA, demonstrates "a reasonable possibility that the typical firm will be able to develop and install engineering and work practice controls that can meet the PEL[20] in most of its operations. OSHA can do so by pointing to technology that is either already in use or has been conceived and is reasonably capable of experimental refinement and distribution within the standard's deadlines…."[21] A standard is not technologically infeasible just because OSHA cannot show it has actually been met or has no studies demonstrating proven effectiveness. The courts do not require OSHA "to prove with any

[17] See, *Id*.
[18] *Forging Industries Association v. Secretary of Labor 773 F.2d 1436 (4th Cir. 1885)(en banc)*
[19] *Id.*
[20] PEL: Permissible exposure limit
[21] *United Steelworkers of America v Marshall, 647 F.2d 1189 (DC Cir 1980)*

certainty that industry will be able to develop the necessary technology or even to identify the single technological means by which it expects industry to meet the PEL."[22]

OSHA may impose a standard only the most technologically sophisticated workplaces have been able to meet even if only in some operations, some of the time. "OSHA can require industry to meet PELs never attained anywhere."[23] It can also force industry to "invest all reasonable faith in its own capacity for technological innovation"[24] by developing and diffusing new technology. When OSHA relies on the development of new technology to establish the feasibility of a standard, it must provide a compliance horizon long enough to allow such development.

The test of economic feasibility is well settled. As the D.C. Circuit explained in *United Steelworkers v. Marshall* a standard is not infeasible "simply because it is financially burdensome."[25] Even where the predicted costs of compliance with a standard are "initially frightening" courts require OSHA to "examine those costs in relation to the financial health and profitability of the industry and the likely effect of such costs on unit consumer prices."[26] The practical question is whether the standard "threatens the competitive stability of an industry or whether any intra-industry or inter-industry discrimination in the standard might wreck such stability or lead to undue concentration."[27]

To prove economic feasibility, the court "probably cannot expect hard and precise estimates of costs" particularly where OSHA predicts a firm's technological capacity to comply. OSHA must, however, make a "reasonable assessment of the likely range of costs and the likely effects of those costs on the industry." [28]

In developing cost estimates, OSHA can revise numbers submitted to it by industry. It can eliminate sources of double counting. It can assume industry compliance with existing law. OSHA's cost estimate must reflect the incremental cost of increased regulation; expenses that would be incurred in the absence of regulation are not properly attributed to the rule. OSHA may group "large categories of industries together" so long as it provides "some explanation of why findings for the group adequately represent the different industries in that group."[29]

L&I finds the ergonomic standard is technologically and economically feasible in all affected industries. The technology to reduce hazardous employee exposure to physical risk factors is readily available to business. Simple solutions often work best. Further, the extended time frame for achieving compliance creates an opportunity for developing new technology to achieve compliance. L&I also finds that compliance with the rule is economically feasible and that the benefits of the rule outweigh its costs.

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[22] *Id.*
[23] *Id.*
[24] *Id.*
[25] *Id.*
[26] *Id.*
[27] *Industrial Union Department v. Hodgson.*
[28] *United Steelworkers of America v Marshall, 647 F.2d at 1266*
[29] *AFL-CIO v. OSHA, 965 F.2d 962* (11th Cir. 1991).

HEALTH EFFECTS: WMSDS ARE SERIOUS AILMENTS AND ARE CAUSALLY RELATED TO SPECIFIC RISK FACTORS FOUND AT WORK.

WMSDs are serious ailments resulting in material impairment to health and functional capacity

Musculoskeletal disorders are injuries and illnesses that involve the bones, joints, muscles, tendons, nerves and supporting structures. WMSDs, for the purpose of this rulemaking, are the work-related non-traumatic soft tissue musculoskeletal disorders, such as carpal tunnel syndrome, tendinitis, rotator cuff syndrome, and low back strain. Exposure to physical risk factors at work (such as awkward postures; high hand force; highly repetitive motion; repeated impact; heavy, frequent or awkward lifting; and moderate to high hand-arm vibration) is known to cause or aggravate these WMSDs. These disorders often develop in workers whose jobs involve repetitive tasks or manual handling. WMSDs may occur after hours, days, months or years of exposure. The symptoms of these disorders may appear to have a sudden onset or they can begin slowly and develop over a long period of time.

Three examples are illustrative:

- Carpal tunnel syndrome is a classic entrapment neuropathy, caused by compression of the median nerve as it passes under the transverse carpal ligament on the flexor side of the wrist. Numbness, tingling, and pain in the fingers are common features, often waking the worker in the middle of the night. Aching pain may radiate into the forearm and may be worsened by manual activity, particularly bending or flexing the wrist. Sensory disturbances may be followed by muscle weakness and atrophy. The pain, reduced motor strength and disturbed sensory feedback can interfere with the ability to perform fine manual tasks such as light assembly work, keying or sewing. As the condition progresses with muscle wasting and increased pain, everyday activities such as driving a car or even dressing can become excruciating or even impossible. Workers with carpal tunnel syndrome may be treated with work restrictions, wrist splints, anti-inflammatory medications, physical therapy, or corticosteroid injections. Surgical release of the carpal ligament may relieve the symptoms but may not return ability to work. Despite aggressive treatment workers may experience temporary or permanent total disability.

- Lateral and medial epicondylitis are the terms for inflammatory disorders of the tendons that connect the muscles of the forearm with the bone of the upper arm (humerus). Pain and tenderness may be so severe that simple movements or exertions such as reaching for parts or handling control knobs become impossible. Treatments include short or prolonged periods of rest, oral anti-inflammatory drugs, physical therapy, anesthetic and corticosteroid injections, or surgical release procedures.

- Sciatica is impingement of the sciatic nerve, often by a herniated disc in the lumbar spine, as the nerve root leaves the spinal cord. Severe pain radiating down one or both legs may cause

> difficulty in sitting or walking, worsened by bending or twisting. Patients often complain of pain, numbness, and weakness that are only relieved when confined to bed or in a flexed position. Conservative treatments such as limited physical activity, non-steroidal anti-inflammatory drugs, muscle relaxants and opiates, or spinal manipulation are sometimes effective. Many workers with sciatica experience prolonged or repeated periods off work. Surgical intervention may be required if disc herniation has been confirmed, in some cases shortly after symptoms began, sometimes after some weeks or months, and sometimes as a last resort after other treatments fail.

WMSDs do not kill workers, but they can have a devastating impact on their lives and livelihoods. The cardinal signs and symptoms include pain, motor weakness, sensory deficits and restricted ranges of motion. These can be severely debilitating, but even in modest, early stages they can interfere with both work and family life. Also, problems that are reversible in early stages can become permanently disabling. Numerous studies have demonstrated long-term impairment after prolonged exposure to the hazards regulated by this rule. (Punnett, comments) For example, musculoskeletal symptoms persist into retirement among manual workers who performed heavy physical work in shipyards compared to office workers (Berg, 1988). Persistent neck pain and evidence of arthritic changes including decreased range of motion were present in steelworker grinders exposed to very heavy neck/shoulder loads 8 years after leaving the work (Alund, 1994).

A worker in pain loses the ability to concentrate, causing declines in quality and productivity at work. A worker with muscle weakness will struggle to perform manual tasks and may not be able to perform them at all. A worker with damaged nerves loses accuracy and placement in fine manipulative work, becomes clumsy and inaccurate, and may not respond quickly and precisely to danger. A worker with restricted movement cannot complete tasks or can only complete them by adopting awkward, unnatural postures, which themselves cause additional problems.

Additionally, all of these functional deficits at work are brought home at the end of the day. Pain, weakness, sensory loss and limited movements all can interfere with family responsibilities and relationships. Parents may lose the ability to hold their children. They may not be able to prepare meals, maintain a clean home, perform household maintenance, or enjoy their hobbies. Physical limitations can lead to emotional stress, damaged relationships and loss of self worth. Employee testimony from the public hearings provides examples:

> "I couldn't push a vacuum cleaner; I couldn't pull weeds in the garden; I couldn't brush my teeth with a regular toothbrush; I had to buy an electric toothbrush and hold it with two arms. Thank heavens for technology. I couldn't hold a knife strong enough, long enough, hard enough to chop an onion; and it hurt to put a sweater on over my head. When I was losing sensation in my fingers and I hurt through my wrist, and I thought, I might have grandchildren someday, and I will want to hold them, and if I'm going to hold them, I'm going to need to be able to feel them…My kids had a hard time, too. I looked normal, so they didn't understand why I couldn't go to the grocery store alone. I couldn't push the grocery cart. This is not a trivial problem." (Lila Smith testimony)

> “ My whole life, both professional and personal, has changed, and each day is a challenge to deal with the pain and the numbness and tingling sensations that I feel. Many days I maintain a normal routine; however, the pain is never completely gone, and some mornings I awaken to such an amount of pain, with the inability to use my hands for even the simplest task, such as getting ready for work and driving to work.” (Sally Bearce testimony)

> “We were planning on sending her around the world on our sailboat, but we can’t do that because she cannot handle the sails, steer the boat, or do any of those common tasks…She can no long vacuum floors. She can’t even go to the grocery store by herself because she can’t reach up to get the stuff off the shelves. She can’t push the cart.” (Tom Plummer testimony)

> “I had difficulty functioning on a daily basis. To perform normal tasks like cutting vegetables, pulling weeds, driving, doing laundry, putting gas in my car or scrubbing my kitchen floor caused me extreme pain.” (Susan Silva testimony)

There is strong scientific evidence that jobs and tasks with various physical risk factors expose workers to preventable hazards that can cause or aggravate WMSDs. These risk factors include awkward postures; high hand force; highly repetitive motions; repeated impact; heavy, frequent, or awkward lifting; and moderate to high hand-arm vibration.

Many of the relationships between physical risk factors and MSDs were first reported by clinicians in case series reports or in reviews of workplace medical data. As early as 1713, Ramazzini described “…certain violent and irregular motions and unnatural postures of the body, by reason of which, the natural structure of the vital machine is so impaired that serious diseases gradually develop therefrom.” (p. 435)

In the last 20 years hundreds of laboratory and epidemiological studies have demonstrated the relationship between work-related factors and MSDs. Much of this scientific data has been critically evaluated (Bernard 1997; NRC 1999; Hagberg, et al., 1995; Riihimaki and Viikari-Juntura, 1999; Punnett and Bergqvist 1997; Keyserling 2000a and 2000b in press). In addition, population surveys have been used to assess the prevalence, incidence and distribution of MSDs across industries and occupations (Bureau of Labor Statistics Occupational Injury and Illness Survey, National Health Interview Survey).

Epidemiological studies have looked at the relationships between workplace exposures and outcomes such as symptoms, physical examination findings, specific diagnoses, or disability, while controlling for potential confounders and effect modifiers such as gender, age, injury and medical history. In 1997, the National Institute for Occupational Safety and Health (NIOSH) identified over 2,000 studies, examined over 600 epidemiological studies and published a comprehensive review of the epidemiological studies of back and upper extremity MSDs and occupational exposures (Bernard 1997). The criteria used to assess this literature included: 1) strength of the association, 2) coherence of evidence or biological plausibility, 3) consistency with other research, 4) temporality or appropriate time sequence, 5) specificity of effect or association, and 6) dose-response relationship (biologic gradient).

NIOSH concluded that there was adequate evidence for causal relationships between MSDs of several body regions and repetitive motion, forceful exertions, non-neutral postures, vibration, and combinations of occupational exposures (Table 1). "A substantial body of credible epidemiologic research provides strong evidence of an association between musculoskeletal disorders and certain work-related physical factors when there are high levels of exposure and especially in combination with exposure to more than one physical factor (e.g., repetitive lifting of heavy objects in extreme or awkward postures." (Bernard 1997, page xiv).

Table 1
Summary of NIOSH Review of Epidemiological Evidence for Upper Extremity and Low Back WMSDs (Bernard 1997)

MSD Location or Diagnosis	Number of Studies	Force	Static Or Extreme Postures	Repetition	Vibration (Segmental)	Combination
Neck and Neck/Shoulder	> 40	++	+++	++	+/0	(--)
Shoulder	> 20	+/0	++	++	+/0	(--)
Elbow	> 20	++	+/0	+/0	(--)	+++
Carpal Tunnel	> 30	++	+/0	++	++	+++
Hand/Wrist Tendinitis	8	++	++	++	(--)	+++
Hand-Arm Vibration Syndrome	20	(--)	(--)	(--)	+++	(--)
MSD Location or Diagnosis	**Number of Studies**	**Heavy Physical Work**	**Lifting and Forceful Movements**	**Static Postures**	**Awkward Postures**	**Vibration (Whole Body)**
Low Back	> 40	++	+++	+/0	++	+++

Note: +/0 means insufficient evidence, ++ means evidence for causal relationship, +++ means strong evidence of a causal relationship, (--) means the association is not reported in the NIOSH publication.

In 1998 The National Academy of Sciences (NAS) convened a symposium of 74 researchers and ergonomics practitioners to evaluate the research base including the NIOSH review. The NAS report (NRC 1999) found that despite some study limitations, the preponderance of evidence from studies with high exposure contrasts among study groups supports the association between work-related physical factors and MSD development. NAS also concluded that the demonstrated reduction of MSDs in workplaces where these risk factors were reduced strongly supports the association between workplace risk factors and MSDs.

The NAS report (pp. 15-16) said: "Restricting our focus to those studies involving the highest levels of exposure to biomechanical stressors of the upper extremity, neck, and back and those with the sharpest contrast in exposure among the study groups, the positive relationship between musculoskeletal disorders and the conduct of work is clear… There is compelling evidence from numerous studies that as the amount of biomechanical stress is reduced the prevalence of musculoskeletal disorders at the affected body region is likewise reduced. This evidence provides further support for the relationship between these work activities and the occurrence of musculoskeletal disorders."

The NAS report (p. 27) also concludes that: "We find very clear signals on some topics and weaker signals on others – but little in the way of contradiction. Thus, while there are many points about which we would like to know more, there is little to shake our confidence in the thrust of our conclusions, which draw on converging results from many disciplines, using many methods: There is a higher incidence of reported pain, injury, loss of work, and disability among individuals who are employed in occupations where there is a high level of exposure to physical loading than for those employed in occupations with lower levels of exposure. There is a strong biological plausibility to the relationship between the incidence of musculoskeletal disorders and the causative exposure factors in high-exposure occupational setting."

A number of other comprehensive scientific reviews have reached similar conclusions, including Burdorf and Sorock (1997); Hagberg et al. (1995); Punnett (comments); Riihimaki and Viikari-Juntura (1999); Viikari-Juntura and Silverstein (1999); Buckle and Devereux (1999).

The Department is relying on the above-described NIOSH report, the NAS report, as well as the reviews listed in the above paragraph. The Department has independently evaluated the above reports and studies and others referenced in this Concise Explanatory Statement, and finds them to be the best available evidence.

Scientific evidence demonstrates that each of the risk factors regulated by the rule contributes to WMSDs

Each of the six groups of risk factors addressed by this rule (awkward postures; high hand force; highly repetitive motion; repeated impact; heavy, frequent or awkward lifting; moderate to high hand-arm vibration) is discussed below. Although each type of risk factor is discussed here separately, WMSDs are often multifactorial, with more than one risk factor contributing to cause or aggravate the condition. The interaction of factors may result in reduced blood flow (ischemia), cell death, inflammation, degeneration, restricted movements leading to temporary or permanent damage to muscles, tendons, ligaments, cartilage, blood vessels, or nerves. Risk factors are generally evaluated in terms of how much, how long and how frequently they occur and sometimes if they occur in combination with other risk factors, to determine whether they are hazardous. The combined effects of the physical risk factors, modified by intensity and duration, tax the recovery and repair capacities of the body. Inadequate rest schedules deprive the body of recovery time to accomplish repair on strained tissues. Adequate recovery time increases soft tissue tolerance of physical loads. A given load may be harmful only when combined with inadequate recovery periods (Armstrong et al. 1993). Limited exposure may not be harmful and may result in a training effect. The pattern of exposure can be as important as total magnitude or cumulative exposure. For instance, cumulative exposure duration of 4 hours, spread over two 8-hour work days, can be associated with substantially different health effects than a single, one-time exposure of 4 hours. L&I's definitions and choice of exposure levels for the caution zone jobs and the Appendix B hazards in some cases takes into account these multifactorial considerations. The specific evidence for L&I's choices of exposure levels is presented in Tables 7 and 8.

Awkward postures

Awkward postures increase the force required to do a task and compress soft tissues like nerves, vessels and tendons. These postures can occur repetitively or continuously. Static postures (those held over a period of time to resist the force of gravity or to stabilize a work piece) are particularly stressful to the musculoskeletal system. Since blood vessels generally pass through the muscles they supply, static contraction of the muscle can reduce blood flow by as much as 90 percent. The consequent reduction in oxygen and nutrient supply and waste product clearance results in more rapid onset of fatigue and may predispose muscles and other tissues to injury. The increased intramuscular pressure exerted on nerve tissue may result in chronic decrease in nerve function.

Bernard (1997) found strong evidence of a causal relationship between static or extreme postures and neck or neck/shoulder WMSDs and some evidence of a relationship between these postures and shoulder WMSDs and hand/wrist tendinitis. This review found strong evidence for elbow WMSDs and carpal tunnel syndrome only with exposures to a combination of risk factors.

Non-neutral wrist postures elevate carpal tunnel pressure and epidemiological studies report that these wrist postures are a risk factor for carpal tunnel syndrome (Viikari-Juntura and Silverstein 1999; Yoshioka, Okuda et al.1993; De Krom, Kester et al.1990). In a population based study of confirmed carpal tunnel syndrome, Atroshi, Gummesson et al. (1999) found a two-fold greater prevalence for blue collar workers compared to white collar workers, and an increased risk for those reporting excessively flexed or extended wrists more than one hour per day. Blanc P, Faucett et al. (1996) and Tanaka, Wild et al. (1995) have reported similar findings based on US national survey data. The NIOSH review (Bernard 1997) found that awkward wrist postures in combination with other risk factors were more certainly linked with hand and wrist WMSDs than awkward wrist postures alone.

Two major literature reviews have reported an association between awkward neck postures and neck WMSDs (Bernard 1997; Hagberg, Silverstein et al. 1995). Also, Bergqvist, Wolgast et al. (1995) found an association between neck symptoms and the average time per work cycles with >20º neck flexion. Ariens, van Mechelen et al. (2000) believe the evidence is less convincing, but their review excluded a number of positive studies which combined neck and shoulder pain.

There is strong epidemiological evidence that bending and twisting of the trunk are risk factors of low back disorders. In one study in which exposure was observed from video, risk estimates for mild (20-45º) and severe (>45º) flexion, trunk twisting or lateral bending were high (odds ratios 4.9, 5.7, and 5.9, respectively) (Punnett et al. 1991). NIOSH (Bernard 1997) found some evidence for a causal association between working with awkward postures and low back WMSDs, but insufficient evidence linking static back postures alone with low back WMSDs.

Bernard (1997) found a high prevalence of shoulder (rotator cuff) tendinitis in occupations involving overhead work of long duration, such as shipyard welding, but did not find other strong evidence for postural stress and repetition related to shoulder disorders. Since that review, Punnett, Fine et al. (2000) reported a strong association between severe shoulder abduction/flexion of more than 90 degrees and shoulder disorders in a case-control study in automobile workers. An association between neck-shoulder disorders and arm abduction has also been seen for less extreme postures, in the range of 0-30º abduction, especially if the work is static (Kilbom, Persson et al., 1986; Viikari-Juntura, Martikainen et al. 2000; Frost, Andersen 1999). There are at least four studies identifying an increased risk of shoulder disorders with shoulder abduction/flexion more than 1-2 hours (Punnett comments). Holmstrom, Lindell et al. (1992) have also reported severe shoulder pain with overhead work.

Kneeling more than 4 hours per day has been associated with low back disorders (Bernard 1997; Holmstrom, Lindell et al. 1992). Kneeling, knee bending or squatting have been associated with osteoarthritis of the knee in several epidemiological studies (Riihimaki and Viikari-Juntura 1999; Jensen and Eenberg 1996; Maetzel, Makela et al. 1997). Most recently, Sandmark et al (2000) provides even more convincing evidence of the relationship between knee osteoarthritis and knee bending or squatting including evidence of a dose-response relationship. Felson and Zhang (1998) believe that 15-30% of knee osteoarthritis in men may be attributable to jobs that require bending, crouching or crawling in addition to carrying heavy loads.

High hand force

Force is the mechanical effort required to carry out a movement or to prevent movement. The dynamic act of lifting a work piece and the static act of holding that work piece in position both require force, generated by muscles, transmitted through tendons, and exerted by the body on the work piece. Force causes tension, shear force, friction, and irritation on tendons and tendon sheaths, as well as strain at the insertion of tendons on bones. The amount of hand force required for a particular activity is influenced by the grip type, the wrist posture, the slipperiness of the object being handled (coefficient of friction), presence of cold temperature, the use of gloves, whether a tool is vibrating, the hand span required to hold a tool or an object, and the duration and frequency of the forceful exertion. For example, holding a 2-pound object in a pinch grip is biomechanically equivalent in muscle force production to holding a 10-pound load in a power grip (Stetson et al. 1991). However, in a laboratory study, Bao (2000) found this 2-pound pinch grip muscle activity to be slightly lower than the 10-pound equivalent power grip muscle force. Gripping an object in a flexed wrist position requires more force than gripping in a neutral wrist position.

Deviations from a "neutral posture" can dramatically reduce the amount of muscle force translated into output force. Skilled, small-motor activities such as in keying, pipetting, fine sewing or electronics assembly tasks, involve co-contraction of several muscles to generate precisely graded movements, joint stabilization, or holding forces. Thus, substantial muscle activity can be associated with very little net output force. For example, measurements of the weight of a work piece or the finger forces necessary to move a computer mouse may substantially underestimate the potential damage to the muscles, tendons, joints and other soft tissues involved. Cold temperatures, gloves and segmental vibration increase hand force requirements largely because they interfere with sensory feedback to the fingers so tools are gripped harder.

High grip force has been shown to be an independent risk factor of carpal tunnel syndrome (CTS) in epidemiological studies (Chiang et al. 1993). Experimental studies in the laboratory have shown that carpal tunnel pressure increases as a reaction to exertion of force, especially in pinching activities (Viikari-Juntura and Silverstein 1999). Exertion of high hand forces combined with highly repetitive wrist or hand movements greatly increases the risk of CTS or wrist tendinitis (Silverstein, Fine et al. 1987; Armstrong, Fine et al. 1987; Chiang, Ko et al. 1993; Moore and Garg 1994; Stetson, Silverstein et al. 1993). A number of studies have reported high occurrence of elbow and wrist disorders in jobs that involve repetitive forceful movements in awkward postures (Bernard 1997). There were no studies identified in the NIOSH Review (Bernard 1997) that looked at high hand force in occupational populations and found statistically significant negative associations with hand/wrist WMSDs.

Mathiowetz, Kashman et al. (1985) used a neutral wrist and forearm to determine maximum grip and pinch strengths in the general adult population. The average grip strength for 35-39 year old females is 66 to 74 pounds and for males is around 113-120 pounds. Average tip pinch strength is between 11.6-11.9 pounds for females and 17.7-18.0 pounds for males. According to Bystrom and Fransson-Hall (1994) blood flow to the forearm muscles is insufficient for continuous gripping at 10%MVC and for intermittent gripping, above 17%MVC is unacceptable. This translates to about 7 pounds for continuous and 12 pounds for intermittent grip force for females and 11.6 and 20 pounds respectively for men during a two-hour period.

Highly repetitive motion

Repetition is the frequency with which the same motion or pattern of motions is repeated. High repetition may interact with force and posture, but it may also affect tissues independently. For example, increased friction-induced irritation of finger flexor and extensor tendons in their sheaths can result in tendinitis and lead to increased pressure in the carpal tunnel. A modest level of repetition can be protective, since it can increase muscle strength, flexibility and assist blood flow through muscles. Ideal work cycles keep overall repetition rates in a middle zone between the injurious extremes of static contraction and excessive repetition. Brief movement cycles may involve peak accelerations that can exceed tissue elasticity limits during an otherwise moderate task. The biodynamic literature indicates that, even in tasks performed for a short time, the acceleration and velocity of movements may cause damage that would not be predicted by the muscle forces or joint angles alone.

High repetition of work movements has been shown to increase the risk of tendinitis of the wrist and carpal tunnel syndrome (Silverstein 1986, 1987; Latko et al. 1999). High repetition combined with high force increases the risk of tendinitis and carpal tunnel syndrome (Bernard 1997). A high prevalence of rotator cuff tendinitis was found among a group of industrial workers whose work tasks included elevation of the arm above 30º about 10 times per minute

(Frost and Andersen 1999). Kurppa (1991) found jobs involving highly repetitive and forceful movements performed in awkward postures of the wrist to have the highest risk of wrist tendinitis, carpal tunnel syndrome, and epicondylitis. Such jobs have shown incidence rates of 13 to 25 per 100 person years for tendinitis and 6 to 11 per 100 person years for epicondylitis. Shoulder abduction/flexion repeated more than once per minute has been associated with shoulder disorders (Punnett, Fine et al. 2000; Frost and Andersen 1999). Latko, Armstrong et al.(1999) recently found strong evidence of an exposure response relationship between repetition and tendinitis and some case definitions of CTS while controlling for a variety of personal factors. A prospective study found slowing of median nerve conduction among pork processing workers after an average of sixty four days of employment (Kearns et al. 2000).

In the office environment, various keying activities are a repetitive task for the fingers while the activity of the shoulder and neck region is static. A common finding across studies has been that the increase in duration of intensive keying per day is associated with neck-shoulder and upper extremity disorders, the risk being highest after 4-6 hours of intensive keying per day. Punnett and Bergqvist (1997) reviewed the epidemiological literature on upper extremity WMSDs in video display unit operators. Upper extremity soft-tissue disorders were found to be related overall to keyboard use, especially for four or more hours per day among clerical users and in data entry and similarly intensive or repetitive video display unit work. In his rulemaking comments Gerr noted evidence for increased risk when exposed to intensive keyboard work for more than four hours per day.

Some studies found no association between repetition and upper extremity disorders (Stetson, Silverstein et al. 1993; Moore and Garg 1994). In both of these cases, however, the statistical power to find associations was small because there was little contrast in repetitiveness levels among the jobs evaluated. Nonetheless, Moore and Garg did find that percent recovery time in the cycle, one aspect of repetitiveness, to be an important predictor of distal upper extremity disorders along with force. L&I concluded that these studies did not outweigh the cumulative positive evidence.

Compression and repeated impact

Compression of tissues can result when moderately sharp edges, such as tool handles, workbench edges, machine corners, and poorly designed seating concentrate forces on a small area of the body, resulting in high, localized pressure. This pressure can compress nerves, vessels, and other soft tissues, resulting in degraded nerve transmission, reduced blood flow, and mechanical damage to tendons and tendon sheaths. These changes may themselves result in disease or predispose other tissues to damage. For instance, the prolonged use of scissors can cause nerve damage on the sides of the fingers.

Using the hand or knee as a hammer is a form of external tissue compression, known as impact stress. Hand hammering can damage the ulnar artery as it goes through the wrist and palm, leading to ulnar artery thrombosis (hypothenar hammer syndrome). Little and Ferguson (1972) found the prevalence of hypothenar hammer syndrome to be 14% among men repeatedly using the hand as a hammer and 0% among unexposed men. Using the knee as a hammer has resulted in prepatellar bursitis commonly called “beat knee” or “carpet layers knee” (Kivimaki, 1992). While there have been few specific studies of hand hammering, L&I has identified no negative studies. L&I also notes that all the clinical case reports of hypothenar hammer syndrome mention using the hand as a hammer as a causative factor.

Heavy, frequent or awkward lifting

Numerous studies have shown an association between neck and low back disorders and heavy, frequent or awkward lifting (Riihimaki and Viikari-Juntura 1999; Bernard 1997). For example, Latza et al. (2000) reported load characteristics (heavier bricks and stones for construction workers) and increased duration of exposure to heavier loads predicts future low back disorders. None of the psychosocial work factors (monotonous work, time pressure, low job control, poor social support, job satisfaction) was a significant predictor of low back disorders at one year.

Burdorf and Sorock (1997) reviewed both positive and negative evidence of occupational risk factors for low back disorders. They included only those studies that clearly described exposure measures, had quantitative estimates of risk for work-related factors and did not have evidence of severe selection bias. Associations with physical factors at work, psychosocial factors at work and individual factors were assessed in 35 studies. Sixteen of 19 studies reported positive association between back disorders and lifting or carrying of loads. For example, handling of 1-2 patients per shift was significantly related to low back disorders and increased with number of lifts per shift. In the 3 studies which did not show statistically significant increased risk, one was a community based study of working women, one had little contrasts between occupational groups and one showed no influence of frequent baggage carrying by commercial travelers. Nine out of ten studies reported positive associations with frequent bending or twisting of the trunk with risk estimates of 1.3-2.8.   Exposure response relationships were reported in three of these studies. Seven studies dealt with heavy physical load. Four community-based studies had a dichotomous variable and found increased risk (1-5-2.6). There was contradictory evidence on static work postures or repetitive work.   Thirteen studies on whole body vibration consistently showed positive associations with low back disorders. Psychosocial factors and age were both associated with low back pain in several studies. Gender, height, weight, smoking, exercise, marital status and lower education were positively associated with LBD in a small minority of studies in which they were assessed.

Bigos and colleagues have published a series of papers from a prospective study of low back disorders among 3020 workers at an aircraft manufacturing factory (Bigos, Battie et al. 1991; Bigos, Battie et al. 1992a; Bigos, Battie et al. 1992b; Battie, Bigos et al. 1990). A number of rulemaking comments placed special weight on these papers, arguing that they demonstrate a negligible contribution of work-related physical risk factors to the development of low back disorders.   For example, “WISHA’s dismissal of psychosocial factors is in direct conflict with Bigos’ finding that the most statistically significant factors for predicting acute back pain injury claims were non-physical factors. According to Bigos’ longitudinal, prospective study of 3020 Boeing employees, the second strongest variable for prediction, next to pre-existing back problems, were workers’ perceptions of the workplace, including job dissatisfaction.” (United Parcel Service comments) L&I has evaluated the Bigos reports, disagrees with their conclusions and finds they do not change the agency’s decisions about regulating heavy, frequent, or awkward lifting or other risk factors covered by this rule.

Overall, the Bigos reports do not significantly increase our understanding of back disorders in industry, because while some variables reach statistical significance they do not explain much of the variability of the outcomes under study. For example, Bigos, Battie et al. (1992) considered several potential risk factors and found that together they predicted only 7% of the variability in back injury reports (3.3% for medical history, 2.2% for job satisfaction, 1.9% for psychological factors, and 1.2% for physical examination). Workplace risks such as heavy lifting were not assessed with equal rigor. The central finding that previous back trouble predicts future problems has been known for years and does not detract from the need to control workplace risks when they are present.

The Bigos reports have several other serious limitations:

- The participation rate was low, 40.5% of the original sample. The authors reported that the participants did not differ from non-participants with regard to back injuries, but no information is available how these two populations differed with regard to demographic, psychosocial and workload characteristics.
- The phenomenon under study is a <u>report</u> of back injury. It is generally believed that the role of physical vs. psychological or work organizational factors is not similar for the disease and the reporting of it. Most researchers believe that the role of psychological and work organizational factors becomes greater once the tissue injury has occurred. This study simply agrees with those views.
- The assessment of physical workload was inadequate. Only jobs with more than 19 people were analyzed and those only for their maximal load on the low back based on a biomechanical model. Accurate data on physical load factors at the individual level was not reported. The author's conclusions do not take these limitations into account.
- There were no high exposure jobs described and therefore the ability to evaluate dose-response relationships was further diminished. The authors do not discuss this but do admit that their results may not be applicable to physically strenuous jobs.
- The study design included employees with previous back injuries, but did not evaluate the potential impact of physical risk factors on previous jobs.

Other reportedly negative studies of lifting and low back disorders have similar limitations. For example, Feyer, Herbison et al. (2000) conducted a prospective study of low back pain among nursing students, but there was no evaluation of the physical demands of jobs and there was a 1/3 dropout from the study. Gatchel, Polatin et al. (1995) evaluated return-to-work status of 421 back pain patients after one year and found no relationship of disability to workplace risk factors, however there was such significant misclassification (nursing and housekeeping tasks were classified as light) that the findings have little value. Van Poppel, Koes et al. (1998) found no significant difference in incidence of back pain by hours of manual handling among a group of airline cargo handling workers. However, over a twelve-month period 31% of these employees reported back pain. The absence of a dose-response relationship was not surprising since the authors point out there was little variance in the hours of manual handling because all the subjects held similar jobs.

Moderate or high hand-arm vibration

Hand arm vibration (HAV) is segmental vibration or vibration transmitted through the hands. It damages both the small blood vessels and the small unmyelinated nerve fibers in the fingers, resulting in two specific diseases: vibration-induced white finger and vibratory neuropathy. Together, these are called the hand-arm vibration syndrome or HAVS and result in (numbness, loss of finger coordination and dexterity, clumsiness and inability to perform intricate tasks (Gemne et al. 1987). The adverse effects of HAVS have been known since 1911 when "dead fingers" were reported among Italian miners using pneumatic tools and since 1918 among US limestone quarry workers using pneumatic tools. Blanching usually starts at the tips of the fingers but progresses as exposure time increases. In very severe cases gangrene will appear at the fingertips. The most important tool sources include pneumatic tools such as grinders, sanders, drills, impact wrenches, jackhammers, riveting and chipping hammers, and chain saws. Mirbod, Yoshida et al. (1994); Bovenzi (1994); and McGeoch and Gilmour (2000) have identified dose response relationships. Elevated prevalence of HAVS was observed with exposures above $2.5m/s^2$ (meters per second squared) and even higher at more than $5m/s^2$. Segmental vibration has also been implicated in carpal tunnel syndrome (Stromberg, Dahlin et al. 1996).

Hadler (1998) and Bernard (1998) discussed negative and contradictory evidence thoroughly in an exchange of articles. L&I agrees with Bernard's critique and his conclusion that "HAVS has been observed in workers who have used vibrating tools that transmit energy to the hands and arms over a wide range of acceleration levels." L&I does agree with Hadler that HAVS is substantially less common than many other WMSDs, however L&I believes that Hadler understates the problem by focusing on vascular symptoms while the neurologic component of HAVS is more prevalent (McGeoch and Gilmour 2000). L&I also believes that exposures to harmful levels of vibration are common in construction, motor vehicle repair, manufacture of basic metals and maintenance (Palmer, Griffin et al. 2000) and that it is appropriate to regulate control of hazardous levels of vibration where they exist.

Other workplace risks for WMSDs not being regulated by this rule

<u>Mouse use</u>: Currently there is too little information to identify prolonged mouse use as hazardous in the absence of other risk factors such as awkward postures or repetitive movements. Some comments raised concerns about static postures for the shoulder and hand/wrist. The load on the shoulder area increases if prolonged shoulder flexion is required due to mouse placement. Concern has also been raised about static loading of the finger flexor muscles with prolonged pinching/gripping of the mouse. Both of these factors can be addressed through changes in work practices and location of the mouse relative to the keyboard. Therefore, L&I has decided not to regulate mouse use specifically.

<u>Whole Body Vibration</u>: While there is substantial evidence that exposure to whole body vibration is associated with low back and neck disorders, identifying practical ways for employers to determine whether vehicles or other equipment produce hazardous exposures is difficult without triaxial accelerometers. Operators of off-road vehicles (tractors, heavy equipment operators, trucks on logging roads, subway trains) are likely to have the most hazardous exposures, depending on duration, shock absorbers, seats, and tires. Unlike powered hand tools and segmental vibration, there are no specific declared whole body vibration values

available for vehicle models or other equipment. Because of the complexity of exposure assessment, L&I decided that regulation of this hazard is not practical at this time.

Pushing, pulling and carrying: Approximately 7-8% of neck and back WMSDs are associated with overexertion in pushing or pulling, 3.5% with carrying and 31-45% with overexertion in lifting (Silverstein, Viikari-Juntura et al. 2000). L&I decided not to include pushing and pulling in this rule because measurement would require attention to the initial acceleration force as well as the sustained force, the ground surface grade and coefficient of friction, and placement of handles and would therefore be difficult for employers. The complexity of addressing pushing and pulling is illustrated by a series of laboratory based psychophysical studies by Liberty Mutual researchers. They determined that maximum acceptable two-handed push force decreases as distance increases, maximum acceptable two-handed pull force decreases when handles are above the shoulder, and maximum acceptable weight carried decreases as task frequency and carry distance increase (Snook and Ciriello 1991). L&I decided not to include carrying in this rule because most hazardous carrying tasks also involve lifting hazards and do not require separate attention, although this might underestimate the additional effect of fatigue related to carrying heavy loads. Also Foley and Silverstein (1999) found that most employers were unable to differentiate between lifting and carrying.

Psychosocial risk factors (high psychological demands with low decision latitude, low social support): A number of comments suggested that the rule should require identification and reduction of workplace psychosocial risk factors for WMSDs. L&I has considered the evidence and agrees with NIOSH's assessment that psychosocial factors contribute to the development of WMSDs. "Though the findings of the studies reviewed are not entirely consistent, they suggest that perceptions of intensified workload, monotonous work, limited job control, low job clarity, and low social support are associated with various work-related musculoskeletal disorders." (Bernard 1997) L&I decided not to include these factors in the rule because this would have substantially increased the complexity and scope of the rule and would have raised major subsidiary issues regarding the control of workplace organization and relationships. Nonetheless, L&I recognizes the potential advantages of increasing decision latitude in how work is organized as an effective, indirect way of reducing exposure to physical risk factors.

Negative studies do not undermine agency conclusions when the body of evidence as a whole is persuasive

Among the hundreds of scientific studies that have examined the relationship between workplace exposures and MSDs, some failed to find evidence of such a relationship and a small number that purport to demonstrate the lack of workplace causation. In addition to these individual studies there have been several literature reviews that have concluded that the negative findings outweigh the positive. Some of these articles and reviews express extreme statements of denial: "Credible scientific studies…demonstrate that non-physical (and non 'ergonomic') factors cause the vast majority of musculoskeletal symptoms (complaints) and that musculoskeletal disorders (actual injuries) are not the result of the 'risk factors' identified in the proposed rule: repetition, static postures, awkward postures, force, contact stress, vibration, cold temperature." (Bigos, attachment to United Parcel Service comments) Others are more reserved statements about the strength of the evidence: "There are no conclusive scientific studies showing objective findings that there is a causal relationship between specific work activities and the development of complaints termed 'repetitive strain injury'." (California Orthopedic Association as quoted in United Parcel Service comments)

L&I has considered these studies and reviews that find little or no evidence of work relatedness and finds that they do not invalidate the agency's conclusions about the positive relationship between physical risk factors and WMSDs. Among the principle negative review papers are those by Vender et al. (1995); Blume and Sandler (1997); Smith (comments); Hadler (1996, 1998, UPS comments); and Bigos (UPS comments).

Vender et al. reviewed articles addressing the causes of upper extremity MSDs. L&I has evaluated this review and considers its methods and conclusions to be faulty. The authors considered 2054 "potentially relevant" articles and then decided not to evaluate 2002 of them because researchers did not write them who were either very active in the field or frequently cited as authoritative sources. Every one of the remaining 52 was declared invalid because of methodological features considered faulty by the authors. These included such features as relying upon medical history and physical examination for diagnosis instead of electrodiagnostic tests, and using general diagnostic categories such as "upper extremity disorders" instead of specific diagnoses such as "carpal tunnel syndrome." L&I considers these review criteria to be excessive and inconsistent with well established quality criteria used widely within the scientific community. The conclusion of this review was that "sufficient evidence does not exist in the medical literature to conclude that work is the sole cause of so called 'cumulative trauma'." Even if L&I accepted the manner in which this conclusion was reached, it would have no impact on this rulemaking. L&I agrees that work is not the sole cause of MSDs.

Blume and Sandler prepared an unpublished, non-peer-reviewed critique of NIOSH's literature review (Bernard 1997) for the National Coalition on Ergonomics. Their primary criticism is that NIOSH did not analyze the contribution of individual and psychosocial factors to WMSDs in the same detail as it analyzed work-place physical factors. They also discounted the NIOSH conclusions because NIOSH did not review any animal studies, laboratory based human studies or intervention studies and did not present quantitative dose-response data. The authors also found fault with NIOSH for not having undertaken a quantitative "weight of the evidence" analysis. L&I does not find the Blume and Sandler critique convincing. NIOSH gave appropriate consideration to psychosocial factors in a separate section of its review. NIOSH gave adequate attention to individual risk factors in its evaluation of each particular study and gave the greatest weight to those studies that considered these and other non-work factors in their study design. NIOSH did not find it necessary to review animal or laboratory studies because there was adequate epidemiological evidence to reach sound conclusions. NIOSH used standard epidemiologic criteria for assessing causality and for evaluating the quality of the studies. Rather than using an arbitrary mathematical scoring scheme for each study as advocated by Blume and Sandler, NIOSH determined whether there was sufficient unbiased information in each study to render it scientifically valid. Unlike Blume and Sandler's critique, the NIOSH evaluation was extensively peer-reviewed using well-established agency methods. It was also found acceptable by a committee of the National Academy of Sciences (NRC 1999).

Smith submitted a review prepared specifically for this rulemaking, supplemented by a review by Karsh, a colleague. Smith does “support the idea of an ergonomic rule to control hazardous workplace conditions that have been established as sources of work-related musculoskeletal disorders…I believe that the scientific literature has established a reasonable relationship between working in certain occupations as well as particular types of hazardous exposures and WMSDs.” However, Smith argues that there is insufficient scientific evidence about the quantitative relationship between exposure and injury to write a rule with specific exposure limits. L&I disagrees and provides the specific evidence the agency relies upon in support of the exposure levels in the rule elsewhere in this document.

Hadler has written a number of critical reviews about the causes of musculoskeletal disorders. A number of comments referenced Hadler as the basis for their opposition to this rule.

- L&I assessed Hadler’s principle review of the evidence regarding the causes of carpal tunnel syndrome (Hadler 1996) at the time it was published and concluded that it was fundamentally flawed in its reasoning and conclusions. L&I’s analysis and conclusions were published as a companion piece to the Hadler editorial (Silverstein 1996) and remain the agency’s view at this time.
- In his principle review of hand-arm vibration Hadler (1998) recognized strong evidence that high levels of exposure are associated with vascular symptoms of hand-arm vibration syndrome (HAVS). He concludes, however that HAVS causes relatively little impairment or disability today and that it is no longer a matter for public concern. Bernard (1998) responded to this review in detail and rejected his arguments, concluding “HAVS has been observed in workers who have used vibrating tools that transmit energy to the hands and arms over a wide range of acceleration levels.” L&I agrees with Bernard’s critique.
- Most recently Hadler prepared a general review of the scientific evidence on behalf of United Parcel Service for the federal OSHA ergonomics rulemaking (Hadler, attachment to UPS comments). L&I has considered this review and the agency’s reasons for rejecting Hadler’s conclusions are presented later.

L&I has also reviewed individual studies that failed to find evidence in support of the agency’s conclusions about the workplace causes of MSDs. There were several design features that made these unlikely to find associations even had they been present. Therefore none by themselves or in combination render the agency conclusions invalid. L&I discounted these when they were inconsistent with a larger body of positive evidence from well-designed studies. There were four main reasons these studies were not persuasive to L&I:

- Inappropriate comparison groups such as no contrasts in exposure among the study groups (Radecki 1995; Atcheson et al. 1998) or inadequate contrasts in health status among the study groups (Atcheson et al. 1998)
- Inadequate measurement or characterization of workplace exposures to physical risk factors (Atcheson et al. 1998; Bigos 1991; Nathan 1988, 1992, 1998)
- Failure to account for the movement of workers from jobs or work areas that involve high-risk exposures. These studies may not include workers who have left the workplace or moved to lower risk jobs because they could not continue to function in the high-risk jobs. In such cases the number of injured people may be higher in the low risk jobs because of past exposures (Schottland et al. 1991) One particular form

this design flaw takes is failure to account for the "healthy worker effect." (Nathan 1988)

Other common weaknesses in study design also predispose to negative results:

- Inadequate sample size: Schottland et al. (1991, for male participants)
- Inappropriate study population for the effects being studied: Nathan (1998)
- Inadequate participation rate: Bigos (1991)
- Inappropriate statistical analysis methods: Nathan (1988, 1992)
- Conclusions not supported by findings: For example, L&I did not question the results reported by Bingham, Rosecrance et al. (1996) but differed with the authors' interpretation and conclusions because previous work exposures were not adequately considered. Also, several researchers have recalculated the data from Nathan et al. (1988) and found a statistically significant difference in risk between the highest and lowest exposure groups, contrary to the article's conclusion.

In addition to the major authoritative reviews by NIOSH (Bernard 1997) and NAS (NRC 1999), a number of other authors have carefully reviewed the scientific literature and put the individual negative studies into proper context. These include Burdorf and Sorock (1997); Hagberg et al. (1995); Punnett (written comments); Riihimaki and Viikari-Juntura (1999); Hoogendoorn et al. (1999) and Viikari-Juntura and Silverstein (1999). These reviews provide a more balanced basis for conclusions than those noted above by Vender and Kasden, Blume and Sandler, Smith, and Hadler.

Non-work risk factors do not contradict the findings of work-relatedness

Non-work activities can lead to MSDs. All of the workplace physical risk factors regulated by this rule can also be found outside the workplace. A worker may experience highly repetitive motion while knitting at home, high hand forces or awkward postures while remodeling a room, heavy and frequent lifting from weekly bowling. In some cases a worker may experience exposure to these risk factors only away from work and in other cases may experience them in addition to work exposures.

Individual risk factors such as age, gender, some systemic diseases, anatomic differences, and obesity have also been associated with MSDs. Aging individuals, for example, experience decreased blood flow, impaired nutrition and tissue degeneration that make the back, shoulder and wrist tissues more vulnerable to harmful effects of repeated exertions and awkward postures. Some neck disorders and carpal tunnel syndrome are more commonly reported among women than among men. A biologically plausible explanation could be a weaker muscle force of the upper limbs of women, which would expose women at higher proportional loads of maximal capacity than men during a given task. Low back disorders are more commonly reported by men and may be due to the longer and heavier torso that, when bent, increases the load on the back muscles.[30]

[30] In only a few studies has it been possible to look at differences between women and men, because they usually have different work tasks. Some gender differences obtained in studies may in fact be due to physical load factors not measured in the study.

Musculoskeletal disorders are multifactorial. This means that a single outcome can have more than one cause. For example, the risk of carpal tunnel syndrome is greater if a person is exposed to both repetition and force than to either one alone. Similarly, the risk associated with age combines with the physical risk of heavy, frequent lifting so that an older worker may be at greater risk than a younger worker doing the same lifting job.

L&I received comments from a number of people who felt that these non-work exposures, individual risk factors, combined risks or the occurrence of non-work injuries renders this rulemaking unnecessary, improper, or ineffective:

- "The failure to assess the impact that non-work-related risk factors have on the relationship places employers in the position of having to address injuries and illnesses over which employers have no control." (Association of Washington Business)

- "Yet the proposed rule fails to acknowledge the influence of non-work activities on MSDs. How does an employer quantify an ergonomics hazard if employees' off-the-job activities or pre-existing conditions contribute to their risk?" (Washington State Farm Bureau)

- "Many of the proposed rule features merely exacerbate rather than solve the current workers' compensation situation. These include such things as…ignoring non-work-related activities; omitting employee responsibility for work performance and life style choices." (Puget Sound Chapter National Electrical Contractors Association)

- "The effects of poor posture habits, poor physical conditioning, degenerative disk disease due to the aging process, as well as prior off-the-job injuries will have a huge economic impact as a result of this proposal. And, the proposal is silent with regard to employee responsibility and accountability." (Northwest Food Processors Association)

L&I considered these concerns but concluded they were not relevant to this rulemaking and do not undermine its validity or warrant any changes. Even among employees with non-work risk factors, the presence of risk factors at work increases the risk of injury and this rule is designed to decrease only those workplace risks.[31] It does not regulate individual factors. The rule will provide equal amounts of protection to all workers, regardless of their personal physical condition, but it will not eliminate individual differences in susceptibility. The rule will reduce WMSDs caused in whole or in part by the regulated risk factors, but because the rule does not attempt to regulate non-work exposures or individual risk factors, L&I does not claim that compliance with the rule will eliminate all MSDs among employees. If employers identify and reduce hazards as required by this rule they will be in compliance. The rule is designed so that non-work risks, individual risks or the occurrence of injuries do not result in any additional employer obligations or liabilities.

This ergonomics rule is consistent with other WISHA rules that regulate workplace risks when there are other contributing factors such as aging or non-work exposures. Courts have upheld the

[31] In its evaluation of scientific studies, L&I gave the greatest weight to studies which properly considered and controlled for multiple risk factors and confounding variables, including non-work factors, and which appropriately assessed the workplace contributions to total risk.

right of OSHA and L&I to regulate occupational noise and workplace exposure to tobacco smoke despite the fact that reducing workplace exposures will not completely eliminate the risk if an employee's non-work exposures continue (see above for details). Even in situations where there is a synergistic relationship between work and non-work exposures (e.g. asbestos and tobacco smoke), the agency still has good reason and a duty to regulate the workplace contribution to risk.

ASSESSMENT OF RISK: PHYSICAL RISK FACTORS AT WORK POSE SUBSTANTIAL AND WIDESPREAD RISKS OF WMSDS. ERGONOMICS PROVIDES EFFECTIVE WAYS TO REDUCE OR ELIMINATE THESE RISKS

High numbers and rates of work-related musculoskeletal disorders constitute a major occupational safety and health problem in Washington workplaces. WMSDs are the largest category of injuries and illnesses affecting Washington workers.

The Washington State Department of Labor and Industries (L&I) data on workers' compensation claims provides the most complete and best available information on workplace injuries and illnesses in the state. Nearly all Washington employers (approximately 160,000) obtain workers' compensation insurance through a State Fund operated by L&I. About 400 large employers, employing about one third of the employees in the state, are self-insured. More than 250,000 workers compensation claims are accepted and paid each year. These include more than 65,000 compensable claims, those resulting in four or more days of lost work and which receive both medical payment and partial wage replacement. The rest are non-compensable and receive only medical payments.[32]

Numbers of WMSD claims

For employers covered by the State Fund, WMSDs such as tendinitis, carpal tunnel syndrome and low back disorders are the leading source of injury and illness to workers. Non-traumatic soft tissue WMSDs of the neck, back and upper extremity alone account for 26 percent of all accepted claims and 40 percent of all claims costs. There were 392,925 such accepted claims from 1990-1998, or over 43,000 such claims each year (Silverstein, Viikari-Juntura and Kalat 2000). The total direct workers' compensation cost for these claims (medical cost and partial wage replacement) during 1990-1998 was more than $3.7 billion. Time loss for these WMSDs during 1990-1998 exceeded 20.5 million lost workdays, accounting for 47 percent of all lost workdays over this period.

For the self-insured employers, there were 80,230 compensable WMSD claims for the neck, back and upper extremity between 1990-1998, accounting for 47 percent of all compensable claims accepted by these employers.[33] The claims costs for these self-insured compensable claims exceeded $1.1 billion.

[32] Compensable claims make up approximately 32% of all claims among self insured employers and 24% among employers covered by the Washington State Fund.

[33] L&I does not maintain data on non-compensable (medical only) claims among the self insured employers. Also, data on compensable claims from the self-insured employers are not available to L&I until after the claim has been closed.

Combining data from state fund and self-insured employers, there are at least 52,000 WMSD claims for the neck, back and upper extremity accepted yearly for an annual direct cost of $411,000,000. These are substantial underestimates because L&I does not have self-insured employer data on non-compensable claims or from open compensable claims.

Incidence rates for WMSD claims

Among state fund employers the average annual incidence rate for all neck, back and upper extremity WMSDs is 35.5 per 1,000 FTEs. The highest rate has been for back (19.4 per 1,000 FTEs), followed by upper extremity (11.7 per 1,000 FTEs. Rates for specific diagnoses[34] include 2.5 per 1,000 FTEs for carpal tunnel syndrome, 1.5 per 1,000 FTEs for rotator cuff syndrome, 1.1 per 1,000 FTEs for epicondylitis and 0.5 per 1,000 FTEs for sciatica (Silverstein, Viikari-Juntura and Kalat 2000).

For all compensable WMSDs of the neck, back and upper extremity among state fund employers the average annual incidence rate is 12.9 per 1000 FTEs. For specific disorders the rates are 1.6 for carpal tunnel syndrome, 0.9 for rotator cuff syndrome, 0.5 for epicondylitis, and 0.4 for sciatica. Among self-insured employers the average annual incidence rate for all compensable WMSDs of the neck, back and upper extremity is 16.4 per 1000 FTEs. The highest rate was for back disorders (8.6 per 1000 FTEs) followed by upper extremity (5.6 per 1000 FTEs).

WMSD rates have declined during the 1990's in the absence of a rule and a number of employers have suggested that a rule is therefore unnecessary. For example, "According to your Department's statistics, musculoskeletal injuries have declined 28% since 1990…Any injury is a tragedy but the numbers have to be put into perspective. Clearly the MSD 'crisis' does not exist and for this reason the proposal is premature and unnecessary to promulgate." (Association of Washington Business comments) L&I notes, however, that while the rate of all workers' compensation claims has been declining during the 1990's the rate for WMSDs has declined more slowly and the proportion of all claims represented by WMSDs has increased. Moreover, the rate of decline in WMSDs has slowed considerably in the past few years and in several important industry groups and for some types of WMSDs the rates have flattened completely or actually increased.

- Among State Fund employers, there was a 20.4% drop in WMSD rates from 1992 to 1997 (Silverstein, Viikari-Juntura and Kalat 2000). From 1992 to 1995 the rate declined 5.1% per year, but from 1995 to 1997 the rate declined only 2.0% per year.
- Among self-insured employers the overall decline in compensable claims from 1992 to 1997 was 11.3%. From 1992 to 1995 the annual decline was 3.7%, but from 1995 to 1997 there was only a negligible decline of only 0.1% per year.
- This recent flattening of WMSD rates is more pronounced in several of the highest risk industries. For example, among State Fund masonry employers the WMSD rate dropped 6.6% per year from 1992 to 1995 and 2.6% per year from 1995 to 1997. The comparable annual rate changes were 6.4% and 3.8% for roofing and 9.0% and 4.1% in sawmills.

[34] The Washington State workers' compensation system uses the International Classification of Diseases (ICD-9) for diagnostic coding.

- For some high-risk State Fund employer groups such as carpentry, residential construction, and local transit the rates increased from 1995 to 1997. Rates also increased from 1995 to 1997 for some high-risk self-insured employer groups such as sawmills, trucking and courier services, and air transport.
- For State Fund grocery stores and nursing homes WMSD rates declined more consistently throughout the entire period. Among self-insured grocery stores and nursing homes, however, the declining rates from 1992 to 1995 slowed considerably from 1995 to 1997.

Thus, despite some positive trends, the pace of improvement has slowed and WMSDs still account for unacceptably high numbers of claims and very high claim costs. L&I seeks sustained or increased improvement rather than a continuation of recent trends and believes that this is not possible without the additional stimulation provided by a rule, particularly with regard to those employers who are most resistant to voluntary approaches.

WMSD risks are substantial and exceed many other risks

The workplace risks of WMSDs exceed those for other workplace risks and far exceed any reasonable definition of "average risk." (Figure 1) The average annual risk of all neck, back and upper extremity WMSDs among state fund employers is 355 per 10,000 FTEs for all WMSDs. The average annual risk of all neck, back and upper extremity compensable WMSDs among state fund and self ensured employers combined is 134 per 10,000 FTEs. The risks for other types of injuries include 21.3 for fractures, 8.6 for serious traumatic head and brain injuries, and 3.0 for burns. Risks for other sources of injury incude: 24.2 for falls from elevation, 10.6 for ladders, 8.7 for motor vehicle-related injuries, 7.8 for electrical apparatus, 4.6 for mechanical transmissions, and 3.4 for conveyors.[35]

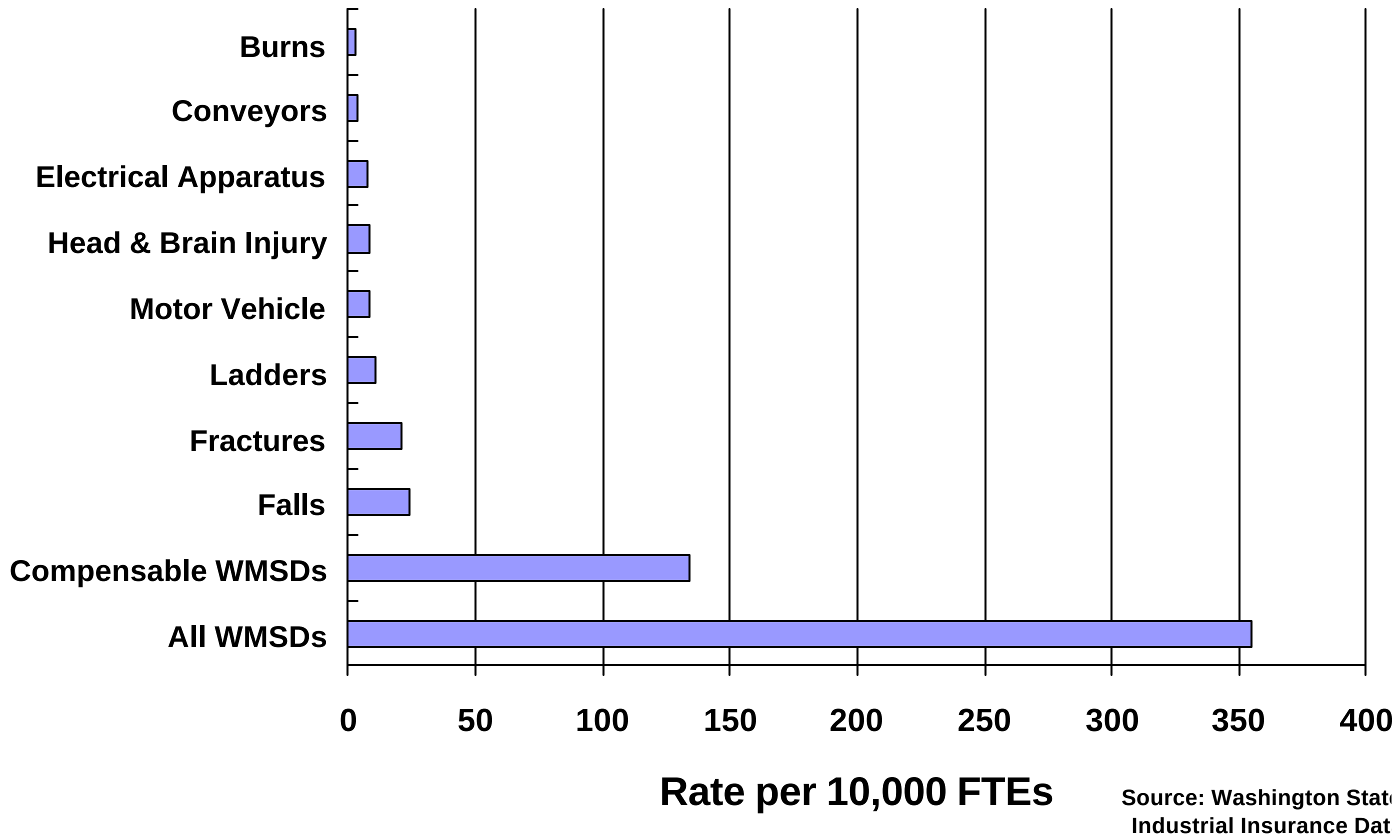
The WMSD risks are also higher than others using BLS data for comparison. For example, the 1997 BLS survey reports the incidence rate for overexertion and repetitive trauma lost workday cases in private industry to be 113 cases per 10,000 FTEs.[36] This compares to rates of 49 for falls, 83 for contact with objects and equipment, 15 for exposure to harmful substances, 11 for transportation accidents and 3 for assaults and violent acts. Many specific hazards that are regulated have far lower risks, such as ladders (1.7 per 10,000), stairs and steps (2.1), metal and woodworking machinery (3.4), and mining and drilling machinery (24.4).[37] These comparisons are imperfect because the non-WMSD rates represent risks following rather than before regulation. Pre-regulation injury and illness rates are available for a limited number of OSHA and WISHA rules and they are also typically far lower than the WMSD rates. For example, OSHA estimated a pre-regulation rate of cancer from benzene exposure at the existing limit to be 80 cases per 10,000 workers over a 45 year working lifetime or less than 2 per 10,000 per year.

[35] 1998 data from Washington State Department of Labor and Industries Data Analysis Unit; Silverstein, Viikari-Juntura and Kalat, 2000; and Cohen, 1999

[36] BLS Table #17 Incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full time workers for selected events or exposures leading to injuries or illnesses and industry division, 1997

[37] BLS Table #16 Incidence rates for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full time workers for selected sources leading to injuries or illnesses and industry division, 1997

Figure 1
Claims Rates for WMSDs and Other Injuries, 1998



L&I believes that the Washington State workers' compensation data is the best available data on workplace injuries and illnesses for this rulemaking. The only other statewide data for workplace injuries and illnesses is from the annual U.S. Bureau of Labor Statistics (BLS) survey. L&I considers the BLS data less complete and reliable than the workers' compensation data for the following reasons. First, the BLS data uses a statistical sample of workplaces in the state while the workers compensation data includes every employer. Second, the BLS data is from employer self-reports with some quality control checks by survey staff while the workers' compensation claims are subject to appeal and have been formally adjudicated. Third, the BLS data employs an artificial and inconsistent distinction between injuries and illnesses, which makes interpretation difficult. For example, the BLS classification system considers all back disorders to be injuries, while upper extremity WMSDs can be classified as either injuries or illnesses. Using the workers' compensation data provides L&I with much greater ability to analyze the information in the most meaningful way.

Despite its shortcomings the BLS survey data validates the conclusion that WMSDs are the leading workplace injuries and illnesses in the state. In 1997 the BLS State survey reported 188,000 total occupational injuries and illnesses, 78,000 of which were lost workday cases. There were 13,300 occupational illnesses, 8,300 of which were disorders associated with repeated trauma. These repeated trauma cases are only a subset of the full group of WMSDs related to the risk factors covered by this rule. BLS data on the other WMSDs is available only for private sector employers and for lost workday cases.[38] Within this group there were 2,488 repeated trauma cases and an additional 16,671 cases from overexertion and 2,935 from bending, climbing, crawling, reaching and twisting. In other words, for every repeated trauma case (among the private sector lost workday cases) there were 7.9 other WMSD cases. Applying this ratio to the 8,300 total repeated trauma cases there were approximately 65,570 additional WMSD cases for a total of 73,870. This compares well with the 52,500 annual neck, back and upper extremity WMSD cases estimated from the workers' compensation data, considering that the claims data does not include lower extremity claims or self-insured employer data on non-compensable claims or from open compensable claims.

A number of commenters, including the Association of Washington Business, have compared L&I's estimated number of WMSD cases with the BLS number of repeated trauma cases and argued that "neither state nor federal data sources provide a basis to understand these widely divergent MSD estimates."[39] But, as noted above, the BLS repeated trauma cases are only a subset of the WMSD cases and understate the total number by a factor of 7.9. The above explanation adequately reconciles any apparent differences and demonstrates that the estimates from BLS and workers' compensation claims are not widely divergent.

Workers compensation data and BLS reports both tend to underestimate the magnitude of the problem (Silverstein 1997; Morse, 1998; Pransky 1999). There are a number of disincentives for workers and health care providers to report problems, including fear of reprisals, loss of income, change in job status, peer pressure, and paperwork. (Spieler 1994) Employees who testified at

[38] BLS Table #13 Number of nonfatal occupational injuries and illnesses involving days away from work by event or exposure leading to injury or illness and industry division, 1997

[39] Economic Analysis of the State of Washington's Proposed Ergonomics Rule, prepared for the Association of Washington Business by M. Cubed, San Francisco, California.

the hearings indicated that they and their co-workers often left WMSDs unreported. (Joanne Keenan, Patrick Burns, Al Link, Edward Wood, Anna Guzman comments)

The cost of WMSDs is very high

Although L&I has concluded that WMSDs pose significant risks without considering their costs, WMSDs also impose a very large economic burden on the Washington State economy. For WMSDs of the neck, back and upper extremity alone the annual direct cost (medical cost and partial wage replacement) is more than $411 million ($284 million for State Fund employers and $127 million for Self-Insured employers). (Table 2) These figures do not include the costs for WMSDs of the lower extremity or the costs for non-compensable (medical only) claims for self-insured employers. L&I estimates the full annual direct costs of industrial insurance claims for the types of WMSDs addressed by the rule to be greater than $450 million.

The actual total cost is much higher than these measurable direct costs. First, insurance payments do not fully compensate workers for lost time and income. Second, there is evidence that workers make sizable out of pocket payments to treat WMSDs. (Morse et al. 1998) Third, there are other sizable indirect costs associated with WMSDs. These are borne by the employer in the form of higher absenteeism, turnover and replacement training costs as well as lower overall productivity and quality. (Carter and Boquist 1995; Westgaard and Aaras 1984, 1985; Murphy 1992; Amey 1992; Oxenburgh 1991; Davis 1999; Wick and Johnson 1995; Ferris 1992; Burton et al. 1999) Indirect costs are also borne by the employee afflicted with a serious WMSD in the form of reduced long term earning potential and family stability. There is evidence that workers with WMSDs suffer lost earnings long after wage replacement benefits cease (Boden and Galizzi 1999; Reville 1999; Biddle 1998). Indirect employer cost estimates range from 0.5 to 20 times direct costs depending on the method of calculation and the type of injury being studied. (Brody 1990; Heinrich 1959; Andreoni 1986; Hinze 1991; Jack Azar, Xerox comments to OSHA ergonomics rulemaking) L&I's analysis makes the conservative assumption that indirect employer costs are 75 percent of direct costs of WMSDs. L&I estimates the total costs of WMSDs addressed by this rule to be more than $1 billion yearly.

A large amount of costs borne by workers with WMSDs cannot be quantified. These include household economic losses, decreased ability to perform family and social roles, adverse impact on family relationships, depression and loss of self esteem, decreased contribution to community, pain and suffering. While these costs were not included in the formal cost-benefit analysis for this rule, L&I believes that they are large and important and must be a factor in the process of making public policy decisions about ergonomics.

Table 2
Direct Cost of Neck, Back and Upper Extremity WMSDs, Washington State 1990-1998

	Total Number of Accepted Claims	Number of Accepted WMSD Claims	Direct WMSD Cost 1990-1998	Annual Direct WMSD Cost
State Fund Employers	1,489,984	392,925	$ 2,562,630,437	$284,736,715
Compensable	350,358	143,933	$ 2,390,862,444	$265,651,383
Medical Only	1,139,626	248,992	$ 171,767,993	$19,085,333
Self Insured Employers	533,207	--	--	--
Compensable	172,435	80,230	$ 1,142,564,463	$ 126,951,606
Medical Only	360,772	--	--	--
Total	2,023,191	473,155	$ 3,705,194,890	$ 411,688,321

- **Costs in 1998 dollars**
- **This table does not include information on medical-only claims for WMSDs for self-insured employers. This information is not available to L&I. However for the purposes of estimating total WMSD costs in the cost-benefit analysis L&I estimated a cost of medical-only claims for self-insured employers based upon the ratio of medical to compensable claims in the state fund and cost per medical-only claims in the state fund.**
- **Complete costs of compensable self-insured claims are not reported to L&I. Medical costs and indemnity reserves for these claims were estimated based on average state fund claims costs, assuming 25% lower indemnity payments per claim than for state fund employers. See L&I's cost-benefit analysis for more detail.**

The impact of WMSDs is spread widely among industries and occupations in the State of Washington. In some industry sectors the risk to workers is especially great.

WMSDs and their risk factors have been identified in all industry sectors (Bernard 1997; Silverstein, Viikari-Juntura and Kalat 2000; Foley and Silverstein, 1999). Table 3 shows the combined state fund and self-insured compensable WMSD claims rates for the top 20 3-digit SIC industries by prevention index rank. The prevention index averages the rank based on the incidence rate and the rank based on the total number of claims. For example, a very small industry may have a high rate but a small number of claims while another, larger industry with more workers may have a large number of claims but a low incidence rate. Averaging these rankings is a reasonable approach to identifying industries where the overall impact of WMSDs and the opportunity for prevention is the greatest. For an industry to have a high prevention index rank it must have relatively high numbers of WMSDs and relatively high incidence rates of WMSDs. Appendix A provides additional data on the numbers and rates of WMSDs in various industries, along with their prevention index rankings. A large variety of manufacturing, construction and service industries are represented in the groups ranked highest by claims rates, claims numbers and prevention index.

L&I reviewed the data on WMSDs by industry sector to determine whether any sector was particularly unique or if the risks were widespread. L&I did not undertake a detailed industry by industry analysis of significant risk. The evidence indicates that WMSD risks are found across all industry sectors although there is variation. The rule was designed to ensure that hazards would be reduced wherever they occur. Significant WMSD hazards are not limited to the highest risk industry groups. Standard industrial classification codes (SICs) were developed for purposes of commerce and not for estimating hazardous exposures. Many "high risk" occupations or jobs are contained within industry classifications that might be classified as "low risk." For example, janitors and maintenance employees working for a financial company are exposed to many of the manual handling risk factors of concern but would be classified under "finance, insurance and real estate."

Exposure to risk factors and hazards that lead to WMSDs are widespread in Washington workplaces and are found in a wide range of industries and occupations

In 1998, L&I surveyed approximately 5,000 employers, including all industry sectors in the state except mining and maritime (Foley and Silverstein, 1999). The study design (random sample of employers, stratified by industry and size) and a high response rate (75%), provides confidence that the survey was representative of the state's employers as a whole. Participation rates by employer size were quite similar. For example 74.8% of employers in the state are small employers (10 or fewer employees) and 75.6% of the respondents were small employers. There were no significant differences in participation by 1 digit SIC (major industry sector). By 2-digit SIC, there were two small industries (SIC 33 primary metal industry, and SIC 43 US Postal Service) with very low response rates.

Employers were asked about musculoskeletal disorders in the workplace and number of claims filed in the previous three years for musculoskeletal disorders. They were asked whether employees were exposed to any of 15 workplace physical movements or positions that have been identified as risk factors for WMSDs. If yes, they were asked the approximate number of employees exposed to different duration periods or frequencies (Table 4). They were also asked about steps their organization had taken in the previous three years to prevent or reduce WMSDs, the results of these efforts, and any technical assistance they had sought.

The survey found that exposure to WMSD risk factors in the work place was prevalent in every industry sector and in all three sizes of establishments. While many types of work involved exposure to physical risk factors, a smaller subset of workers had prolonged exposure at levels likely to be hazardous. Among responding employers, 43.7% reported no employee exposure to any of the risk factors for more than two hours (48.5% of employers with 1-10 employees, 33.9% of employers with 11-49 employees and 23.9% of employers with 50 or more employees).

Employers in every industry sector reported employees exposed to some risk factors (Table 5). For example, employee exposures to awkward lifting (above the shoulders, below the knees, with a twisted torso) were reported by more than 50% of employers in agriculture, construction, manufacturing, wholesale/retail trade and public administration. Employees lifting more than 50 pounds more than 10 times per hour were reported by 59.9% of construction employers, 54.9% of public administration employers, and 51.8% of durable goods manufacturing employers. About 53% of construction employers and 62% of durable goods manufacturing employers reported employee exposure to vibrating tools. Exposure to working with the hands above the shoulder was reported by 36.5% of agricultural employers, 65.4% of construction employers, 34% of general services employers and 54.6% of public administration employers. Employee exposure to repetitive wrist movements (more than 10 per minute) was reported by 30-54% of employers in agriculture, construction, durable and nondurable goods manufacturing, wholesale and retail trade, general services and public administration. With the exception of agriculture and construction, intensive keyboard mouse exposure was reported by 30-78% of employers in the other sectors.

Many employers acknowledged exposures to risk factors during testimony or in written comments, even as they expressed concern with or opposition to rulemaking.

> "A quick 'eye-ball' review of our positions indicates that we have as many as 94 people in positions that may qualify as caution zone job. These positions…would probably qualify in the areas of high hand force, awkward postures, and moderate to high vibrations." (City of Lynnwood)

> "I have been in business for 22 years and employ 23 people. Most of these jobs are what you refer to as 'caution zone jobs'." (Inland Fire Protection, Inc.)

> "The management of Pacific Aerospace and Electronics, Inc. fully acknowledges that WMSDs are a real and serious problem and that hazards in the workplace can and do cause or aggravate these types of injuries." (Maggie Grim, Pacific Aerospace and Electronics, Inc.)

> "It seems as though many of our jobs qualify as 'caution zone jobs' and will require a workplace hazard analysis." (Ron Speer, Soos Creek Water and Sewer District)

> "We have been in business for 33 years and employ approximately 45 people. Most of these jobs are what you refer to as 'caution zone jobs'." (Randy Mooney, Dan Leslie Roofing)

> "We transload individual boxes or bags of foodstuffs, including frozen meat and poultry and dry grains. The product varies in weight from 30 pounds to 100 pounds and is hand-loaded into push bin attachments to forklifts, then transported to the ocean-containers. The act of loading push-bins is what would be deemed as a caution zone job." (John Odland, MacMillan-Piper)

> "Lifting, lowering, pushing, pulling and reaching are integral to UPS's business; the proposed rule would have a substantial impact on the Company." (Eugene Scalia, United Parcel Service)

Table 3
Annual Compensable Claims Rates for WMSDs for the Top 20 Industries Ranked by Prevention Index (PI)*

PI Rank	Neck Disorders		Back Disorders		Upper Extremity Disorders		All Neck, Back and Upper Extremity WMSDs	
	SIC Industry	Claims Rate	SIC Industry	Claims Rate	SIC Industry	Claims Rate	SIC Industry	Claims Rate
1	805 Nursing and personal care facilities	69.0	805 Nursing and personal care facilities	270.1	174 Masonry, stonework, tile setting and plastering	134.0	421 Trucking and courier services, except air	398.3
2	174 Masonry, stonework, tile setting and plastering	74.6	421 Trucking and courier services, except air	252.5	451 Air transportation, scheduled, and air courier services	114.5	805 Nursing and personal care facilities	402.0
3	836 Residential care	60.6	174 Masonry, stonework, tile setting and plastering	278.1	421 Trucking and courier services, except air	104.0	174 Masonry, stonework, tile setting and plastering	447.8
4	421 Trucking and courier services, except air	38.0	451 Air transportation, scheduled, and air courier services	198.1	541 Grocery stores	88.4	451 Air transportation, scheduled, and air courier services	379.1
5	702 Rooming and boarding houses	50.4	152 General building contractors - residential buildings	179.7	201 Meat products	134.1	152 General building contractors – residential buildings	276.3
6	175 Carpentry and floor work	49.6	175 Carpentry and floor work	213.4	242 Sawmills and planing mills	103.6	176 Roofing, siding, and sheet metal work	443.6
7	152 General building contractors - residential buildings	35.2	176 Roofing, siding, and sheet metal work	305.9	805 Nursing and personal care facilities	85.7	175 Carpentry and floor work	322.4
8	176 Roofing, siding, and sheet metal work	52.3	078 Landscape and horticultural services	202.3	209 Misc. Food preparation and kindred products	98.7	836 Residential care	290.6
9	179 Misc. Special trade contractors	32.9	836 Residential care	175.5	335 Rolling, drawing, and extruding of nonferrous metals	126.6	541 Grocery stores	236.0
10	808 Home health care services	49.4	179 Misc. Special trade contractors	149.7	243 Millwork, veneer, plywood, and structural wood members	84.8	177 Concrete work	393.2
11	078 Landscape and horticultural services	35.9	177 Concrete work	262.2	514 Groceries and related products	77.5	078 Landscape and horticultural services	308.1
12	171 Plumbing, heating and air-conditioning	30.2	734 Services to dwellings and other buildings	153.4	152 General building contractors – residential buildings	76.8	242 Sawmills and planing mills	269.1
13	177 Concrete work	45.6	171 Plumbing, heating and air-conditioning	140.6	176 Roofing, siding, and sheet metal work	104.6	734 Services to dwellings and other buildings	249.9
14	162 Heavy construction, except highway and street construction	31.7	702 Rooming and boarding houses	170.5	202 Dairy products	120.6	335 Rolling, drawing, and extruding of nonferrous metals	341.6
15	344 Fabricated structural metal products	34.6	162 Heavy construction, except highway and street construction	145.0	736 Personnel supply services	64.8	533 Variety stores	287.2
16	734 Services to dwellings and other buildings	30.6	533 Variety stores	170.7	177 Concrete work	101.5	179 Misc. Special trade contractors	231.0
17	753 Automotive repair shops	26.7	541 Grocery stores	125.2	533 Variety stores	84.0	806 Hospitals	215.3
18	172 Painting and paper hanging	38.4	806 Hospitals	124.5	373 Ship and boat building and repairing	97.1	411 Local and suburban passenger transportation	324.7
19	154 General building contractors – nonresidential buildings	28.6	518 Beer, wine and distilled alcoholic beverages	190.2	836 Residential care	77.0	162 Heavy construction, except highway and street construction	229.6
20	411 Local and suburban passenger transportation	42.4	242 Sawmills and planing mills	146.3	721 Laundry, cleaning and garment services	85.1	702 Rooming and boarding houses	250.9

***Incidence rates per 10,000 full time equivalent employees (FTEs); Washington State 1992-1998; combined state fund and self-insured data for industries by three digit SIC codes**

Table 4
Estimated Percent of Employees Exposed to Physical Risk Factors, Washington State Employer Survey, 1998 (Foley and Silverstein, 1999)

Risk Factor	**No Exposure**	**Less than 2 hours**	**2-4 hours**	**More than 4 hours**	**Exposure of Unknown Duration**
Lift/lower objects above shoulders or below knees while twisting	64.3%	9.9%	3.8%	5.5%	16.5%
Lift 10+ lbs. More than once per minute	79.4%	1.9%	1.6%	2.9%	14.2%
Carry heavy loads (30+pounds) more than 7 feet	74.8%	7.4%	1.0%	1.6%	15.2%
Push/pull heavy loads over 7 feet (heavy load = wheeling 200+ pounds or dragging 60+ pounds)	81.0%	4.3%	0.9%	1.0%	12.8%
Use hand or knee as a hammer	94.4%	0.3%	0.1%	0.1%	5.1%
Use vibrating tools — grinders, impact wrenches, etc.	81.1%	2.8%	1.6%	2.1%	12.4%
Repeatedly pinch small objects or tools between thumb and fingers or hold them a long time	76.7%	2.3%	3.9%	2.7%	14.4%
Work with non-powered hand tools	71.1%	4.1%	3.7%	4.0%	17.1%
Work with hands above shoulder level	78.6%	5.4%	1.7%	2.2%	12.1%
Repetitive movement of whole arm more than twice per minute	71.5%	3.7%	2.8%	6.1%	15.9%
Hold fixed position while working (e.g., microscope work)	81.8%	1.6%	1.1%	2.3%	13.2%
Move lower arm(s) more than 10 times per minute (excludes typing)	72.9%	4.3%	4.2%	6.3%	12.3%
Use keyboard/mouse intensively (data entry)	65.8%	4.6%	4.6%	8.1%	16.9%
Sit on vibrating surfaces, machines, vehicles	83.0%	2.2%	1.1%	2.3%	11.4%
Risk Factor	**No Exposure**	**< Once per shift**	**1-9 per hour**	**10+ per hour**	**Exposure of Unknown Duration**
Lift or lower 50 pounds or more unassisted	87.7%	7.6%	3.5%	1.3%	0%

Table 5
Percent of Washington Employers Reporting Any Employees Exposed to Risk Factors*

Task/Risk Factor	Agriculture	Construction	Manufacturing, Non-Durable	Manufacturing, Durable	Transportation	Wholesale, Retail	Finance, Insurance, Real Estate	General Service	Professional Service	Public Administration
Lift/lower objects above shoulder/below knee while twisting	57.5	77.4	59.7	60.8	41.1	55.9	23.8	45.1	36.1	76.7
Lift 10+ pounds more than once per minute	19.3	26.8	21.6	9.2	13.1	13.4	4.6	7.5	4.4	12.1
Use hand or knee as a hammer	1.8	4.4	3.1	4.5	2.6	1.5	0.5	2.5	0.7	0.0
Repeated or prolonged pinch of object/tool	17.2	33.9	14.8	30.2	11.1	13.4	8.0	22.3	19.8	23.5
Work with hands above shoulder level	36.5	65.4	17.1	32.4	19.2	24.6	13.9	34.1	11.5	54.6
Repetitive movement of arm/shoulder more than twice per minute	38.9	55.3	40.2	34.0	23.8	24.7	11.9	32.4	12.5	24.2
Move lower arm(s), hands more than 10 times per minute (exclude typing)	36.7	53.9	40.8	47.2	25.7	30.3	12.1	35.6	18.6	32.3
Use keyboard or mouse intensively (data entry, word processing, graphics)	10.5	26.2	54.9	55.5	38.2	30.4	53.1	32.1	61.7	78.1
Use vibrating hand tools	24.0	52.8	24.6	62.0	18.6	12.7	7.5	27.6	7.8	43.8
Lift/lower 50+ pounds at least once per shift	43.8	59.9	43.0	51.8	36.2	32.7	10.7	25.9	9.9	54.6

*** Adapted from Foley, 1999. Exposures reported irrespective of duration.**

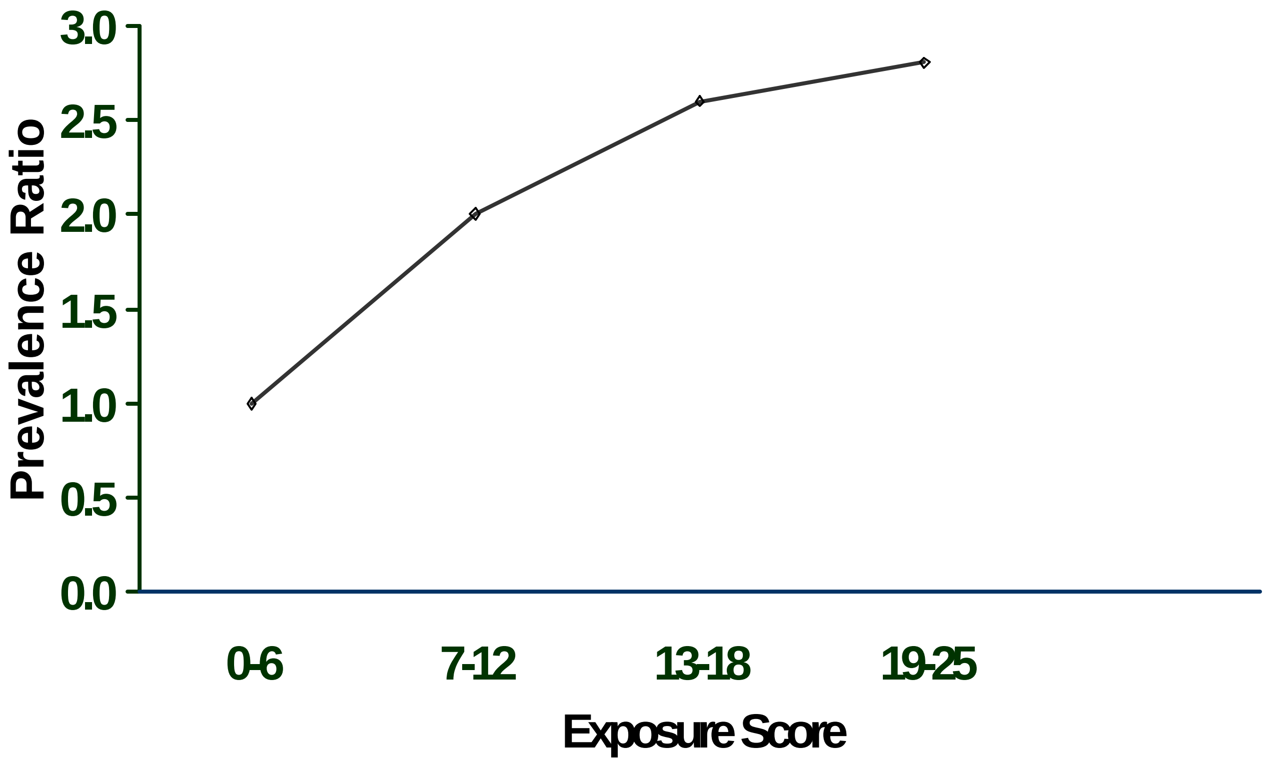
The incidence of WMSDs rises with exposure. Reductions in exposure to risk factors will reduce WMSDs.

Quantitative exposure to physical workplace risks can often be characterized in terms of one or more variables, including amount, intensity, duration, and frequency. A large body of epidemiological and laboratory research has examined the association between a change in the magnitude of one or more of these variables and a corresponding change in the likelihood of injury. A large number of studies demonstrate these relationships between exposure to physical risk factors at work and WMSDs. (see Figure 2 and Appendix B) For example, DeKrom (1990) found a relationship between the duration of exposure to awkward wrist posture and the occurrence of carpal tunnel syndrome. Silverstein (1986, 1987) found a relationship between the frequency and force of repeated movements and the likelihood of hand and wrist disorders.

NIOSH has concluded, "the epidemiologic literature indicates that the greater the level of exposure to a single risk factor or combination of factors, the greater the risk of having a work-related musculoskeletal disorder. The literature also indicates that an important factor is the time between each episode of exposure. With adequate time to recover or adapt, and particularly when lower forces are involved, there may be less harm to the body from repeated exposures…. The intensity as well as the extended length of the exposure to forceful, repetitive work plays a substantial role in the risk of work-related MSDs in many traditional occupational settings." (Rosenstock comments)

Because many WMSDs are caused by the combined exposure to multiple risk factors, some researchers have used exposure indexes that combine multiple risk factors. For example, Punnett (1998) studied WMSD prevalence using an exposure index that combines work pace repetitiveness, grip force, postural stressors, contact stress, vibration, and machine-pacing of work. The prevalence of WMSDs increased markedly as the number of risk factors increased. Similar indexes have been developed by McAtamney and Corlett (1993) in their Rapid Upper Limb Assessment (RULA) tool; by Moore and Garg (1994) in their distal upper extremity Job Strain Index; by Liles (1984) for a Back Job Severity Index; and by NIOSH in the 1991 Lifting Equation (Waters 1993, 1999; NIOSH 1994). It follows from this body of work that multifactorial interventions will often reduce incidence of disorders more effectively than interventions targeting only a single risk factor.

Figure 2
Relationship Between Exposure and Upper Extremity WMSDs



Exposure Score combines repetitiveness, grip force, postural stress, contact stress, vibration and machine pacing; WMSD diagnosis based on physical exams; Punnett 1998

If the likelihood of injury increases as the frequency, duration and intensity of exposure increase, it is logical to conclude that reducing exposure will lessen the risk and will prevent injury. There is a substantial body of empirical evidence, presented below, that this logic is sound and that employing the principles and tools of ergonomics to reduce exposure in fact does result in reduction of injuries. This evidence is not as detailed and exact as the data from controlled animal studies on chemical carcinogenicity that allows mathematical modeling of quantitative dose-response relationships and has served as the basis for OSHA's choice of exposure levels for some chemical hazards. However, this rulemaking is based on direct evidence, primarily from populations of workers exposed at levels comparable to those being regulated, and mathematical extrapolation from high to low doses was not necessary. Also, such theoretical modeling has generally not been required for the regulation of non-cancer hazards. The evidence regarding the causes of WMSDs is sufficiently direct, quantitative and precise to allow L&I to make rational choices about specific levels of exposure for designation as hazards that require control.

There is strong evidence that applying the principles and tools of ergonomics to known risk factors can effectively reduce the hazards to workers and thereby prevent many WMSDs. Ergonomics is the science and practice of making sure that the physical requirements of work match the capacities of the human body.

There have been numerous demonstrations that ergonomics can reduce hazardous exposures and prevent injuries and that these efforts need not be complicated or costly. (Grant and Habes 1995) In addition, they can result in other benefits such as increased productivity, improved employee morale, decreased absenteeism, and better product quality. (Carter and Boquist 1995; Westgaard and Aaras 1984, 1985; Murphy 1992; Amey 1992; Oxenburgh 1991; Davis 1999; Wick and Johnson 1995; Ferris 1992; Burton et al. 1999) NIOSH has concluded, "the science of MSDs also indicates that workplace interventions are effective in prevention… Ergonomics, the science of fitting workplace conditions and job demands to the capabilities of the worker, is proving an effective approach to preventing work-related MSDs…The effectiveness of ergonomics programs was a resounding message echoed by labor, industry, business, universities, health care, and professional societies at two conferences organized by NIOSH and OSHA to stimulate an exchange of information about preventing work-related MSDs." (Rosenstock comments)

For example, in response to a congressional request, the U.S. Government Accounting Office (GAO) in 1997 studied several private sector ergonomics programs. The GAO concluded that these programs yielded positive results: "Our work has demonstrated that employers can reduce these costs and injuries and thereby improve employee health and morale, as well as productivity and product quality…We found that these effects do not necessarily have to involve costly or complicated processes or controls, because employers were able to achieve results through a variety of simple, flexible approaches." (U.S. GAO 1997). Core elements of these successful programs included: management commitment, employee involvement, identification of workplace conditions that may cause WMSDs, development of solutions or controls, training and education for employees and appropriate medical management. Additionally, the GAO study found that "…the processes used by the case study facilities to identify and control problem jobs were typically informal and simple and generally involved a lower level of effort than was reflected in the literature. Controls did not typically require significant investment or resources and did not drastically change the job or operation." (p. 4).

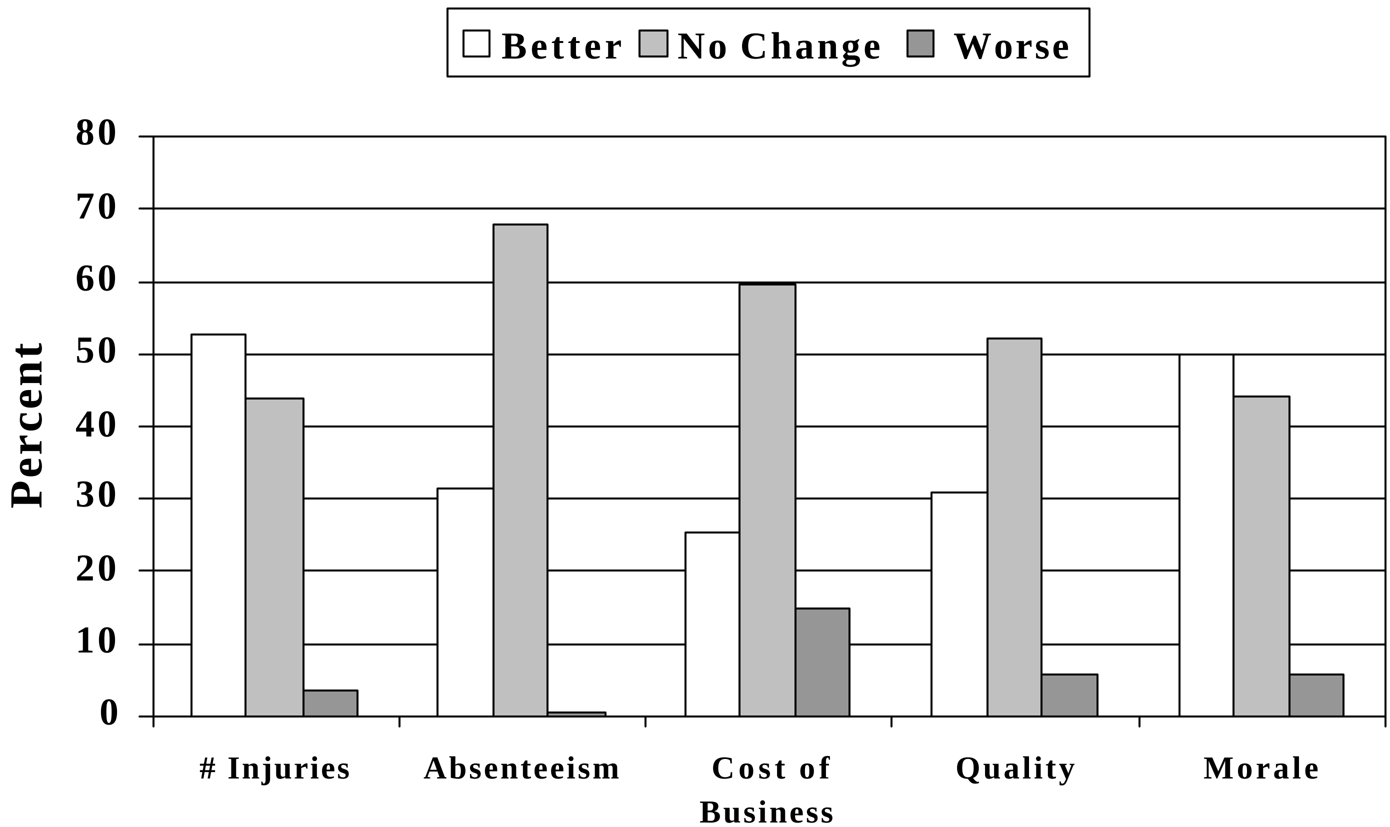
The NAS workshop cited earlier found: "There is compelling evidence from numerous studies that as the amount of biomechanical stress is reduced, the prevalence of musculoskeletal disorders at the affected body region is likewise reduced." (National Research Council 1999, p. 16) NAS goes on to say: "There are a variety of actions that can be taken in the workplace to eliminate or reduce the risk of musculoskeletal disorders. According to the commissioned paper by Smith et al. (1998): 'These include engineering redesigns, changes in work methods, administrative controls, employee training, organized exercise, work hardening, personal protective equipment, and medical management to reduced exposures.'" (p. 18).

There are positive examples from Washington State.

> In the L&I survey of Washington State employers described earlier (Foley and Silverstein 1999), respondents were asked about the steps they had taken to prevent WMSDs in the previous three years. Overall, 36 percent indicated they had taken prevention steps. The responses varied by size and industry, with fewer small employers taking steps. Of those who had taken steps, larger establishments (50+employees) tended to focus on changing workstations, tools and equipment to reduce human exertion (61 percent), provide protective equipment (62 percent), and provide adjustable workstations or equipment (49 percent). Small establishments (1-10 employees) tended to focus on providing more variety of tasks (52 percent), as well as protective equipment (52 percent) and changing workstations, tools or equipment (48 percent). For those establishments taking prevention

steps 53 percent reported a decrease in injuries, 56 percent a decrease in injury severity, 19 percent a decrease in employee turnover and 32 percent a decrease in absenteeism. Improvements in product or service quality were reported by 31 percent and in employee morale by 50 percent. The cost of doing business increased for 15 percent, decreased for 25 percent, and was unchanged for 60 percent of establishments taking prevention steps. Establishments that used engineering or administrative controls reported more success than those using only personal controls such as exercise or personal protective equipment. (Figure 3)

Figure 3
Results of Efforts to Reduce WMSDs



•Foley and Silverstein 1999

A joint labor-management ergonomics team at an aluminum smelter in Eastern Washington was successful in reducing posture and force requirements of carbonsetters (SHARP 1997). The exposure time was cut in half for a number of risk factors similar to those in this rule including handling heavy loads, pinching, and working in awkward postures of the wrist, forearm and shoulder. There was a one-third reduction in the duration that workers were exposed to awkward trunk postures. Following this reduction in exposure, there was a fifty-percent reduction in the prevalence of shoulder, elbow, and back disorders among carbonsetters. Hand/wrist disorders were reduced by one-third. There was no change in prevalence among the comparison group of crane operators.

A team of data entry operators and supervisors at the Washington State Department of Labor and Industries reduced intensive keying time to less than 5 hours, increased task variety, and improved workstations and chairs (SHARP 1993). That resulted in eliminating back and neck disorders and reducing hand/wrist disorders by more than one-third.

Additional examples of successful ergonomics programs were provided during the public hearings or in written comments. Many employers supported voluntary ergonomic programs but opposed a rule.

"In 1994, when we began our ergonomics program at the grassroots stage, we had spent $9 million in ergonomic comp claims. In 1996 we had dropped that to 6 million. And in the last few years, we have averaged $3 million in comp injuries that are ergonomically related. Our program and strategies are very similar to the one proposed in the standard." (Bob Keys, GTE)

"Seattle City Light's office ergonomics program was implemented in 1993…Since the inception of this process City Light has realized significant results including a positive impact on minimizing cumulative injuries through prevention and timely intervention, as well as improvements in employee morale and work efficiency…Cost benefit results indicated that between 1996 and 1997 City Light saved approximately $279,000 and realized a decrease in cumulative work related musculoskeletal disorders for the first time since 1990…Seattle City Light continues to demonstrate a willingness to share information…We have recently worked with several…organizations to develop an ongoing Western Utilities Ergonomics Group to share like ideas, solutions and results, and to solve common ergonomic issues." (Steve Davis, Stewart and Associates)

"Weyerhaeuser started a back-care program in 1988 and, in 1994, began a company wide ergonomics initiative. Our initiative includes training and education, use of site ergonomics teams, and development of materials and tools to help with job/task analysis and improvement efforts. Both office environments and manufacturing/operations have been included in the initiative, which has contributed to a six percent reduction in the number of musculoskeletal-injury workers' compensation claims, and a 40 percent reduction in the cost of these claims between 1996 and 1998." (Paula Stewart, Weyerhaeuser)

> "The Boeing Company cares very much about the impact of ergonomic risk factors on the safety and health of our employees and associated costs to our businesses. To address these concerns, the company has established extensive programs at our Washington sites to prevent musculoskeletal disorders, including cumulative trauma disorders. We have written ergonomics programs at our manufacturing sites in the state of Washington. Boeing has more than 25 employees working on ergonomics issues in our various divisions, plus additional part-time ergonomics focals, and an Ergonomics Technical Committee where our ergonomists coordinate programs and share best practices. We have an ergonomics web site, which offers on-line training and awareness. Other formal training courses on office ergonomics and job-specific manufacturing ergonomics have been developed. Obviously, we believe that ergonomics is an important component of our safety program." (Robert Hollenbeck, The Boeing Company)

> "Our members believe that the science of ergonomics is genuine. We know that ergonomic programs are good for our people and good for business. Each of our plants has working ergonomic programs in place." (Bob Hollingsworth, Aluminum Industry WISHA Affairs Committee)

> "Xerox firmly believes in the value of ergonomics and agrees that an ergonomics standard will be beneficial in protecting workers in those companies that have not embraced ergonomics…We have conducted a cost-benefit analysis of our ergonomic activities at one major manufacturing plant…It is apparent that this investment yielded positive results.""(Jack Azar, Xerox comments to OSHA ergonomics rulemaking)

The scientific evidence and industry experience regarding the positive impact of workplace ergonomics has been the basis for practical control strategies that can be found in numerous texts and guides.

Examples of guides include:
- Ergonomics and the Newspaper Industry, Newspaper Association of America, 1996
- Ergonomics For Carpenters, The UBC Health and Safety Fund of North America, 1995
- Ergonomics Awareness Reference Guide, UAW-GM Human Resource Center, 1991
- The UAW-Ford Ergonomics Action Guide, UAW-Ford National Joint Committee on Health and Safety, 1996
- Partners in Free Motion, UAW-Chrysler National Training Center, 1991
- Ergonomic Improvement of Scanning Checkstand Designs, Food Marketing Institute, 1992
- Simple Solutions: Ergonomics For Farm Workers, National Institute for Occupational Safety and Health, 2000
- Metalcasting Ergonomics, American Foundrymen's Society, 1992
- Strains and Sprains, A Worker's Guide to Job Design, United Automobile Workers, 1982
- Ergonomics, An Interactive Approach to Developing Ergonomic Solutions, Aetna Life and Casualty, 1991
- Elements of Ergonomics Programs, National Institute for Occupational Safety and Health, 1997
- Office Ergonomics Solutions, Center for Office Technology, 1994

- Fitting the Job to the Forest Worker, An Illustrated Training Manual on Ergonomics, International Labor Office, 1992
- An Ergonomics Guide to Hand Tools, American Industrial Hygiene Association, 1996
- CTD News Prevention Handbook, CTD News, 1997
- Power Tool Ergonomics, Atlas Copco, 1997
- Work Practices Guide for Manual Lifting, American Industrial Hygiene Association, 1983
- Ergonomic Checkpoints, International Labor Office, 1996
- Voluntary Ergonomics Program Management Guidelines for Food Distribution Centers, National-American Wholesale Grocers Association, 1996
- A Guide to Manual Materials Handling, Mital, Nicholson and Ayaub, 1993
- Making the Job Easier: An Ergonomics Idea Book, National Safety Council, 1988

Examples of texts include:
- Occupational Ergonomics Theory and Applications, Bhattacharya and McGlothlin, 1996
- Human Factors Design Handbook, Woodson, Tillman and Tillman, 1992
- Ergonomic Design For People at Work, Eastman Kodak Company, 1986
- Cumulative Trauma Disorders, A Practical Guide to Prevention and Control, Peate and Lunda, 1997
- Fitting the Task to the Man, A Textbook of Occupational Ergonomics, Grandjean, 1988
- The Ergonomics Edge: Improving Safety, Quality and Productivity, MacLeod, 1995
- Ergonomics Standards and Guidelines For Designers, Pheasant, 1987
- Industrial Ergonomics, Alexander and Pulat, 1991
- The Occupational Ergonomics Handbook, Karwowski and Marras, 1998
- Occupational Biomechanics, Chaffin and Anderssen, 1986

These texts and guides provide numerous, readily available suggestions for general hazard control strategies and for solutions to specific problems. For example, Peate and Lunda (1997) provide this list for control of upper and lower extremity hazards (See Tables 9, 10 and 11 for other examples):

- Reduce repetition: work enlargement, provide mechanical assists (lifts, turntables), use multifunction tools, change the product or process, allow time to rest
- Alter force required: change the size or shape of objects that are held in the hands, increase the friction of the object in the hand, reduce the weight of hand-held objects, grasp objects with a power grip, grasp objects at their center of gravity, shift the center of gravity, balance tools, use air shutoff or external torque bars, use mechanical assists for turning and holding, when possible slide parts rather than lift, use handles that are long enough to be gripped, replace or service dull and worn tools, avoid gloves that are too bulky or tight, cover only those parts of the hand that must be covered
- Improve posture: design tasks so the work can be performed with the elbows close to the side of the body, allow for frequent change of position, control posture through the location, shape, size and orientation of the work
- Decrease contact stress: increase the size and length of handles, wrap handles with tape or thermoplastic materials, use malleable or compliant materials, cover arm rests with foam, eliminate or pad sharp edges

- Alternate options for standing: a sit/stand chair, a cushioned surface to stand on, foot rests, well-cushioned shoes, avoid using foot pedals when standing
- Avoid kneeling/squatting/crouching/stooping: provide a cushioned surface such as knee pads or padding on the floor, alternate tasks that require kneeling with tasks that do not, avoid awkward positions when foot pedal controls are used.

There is also a substantial body of evidence indicating that safety and health education and training for employees consistently contributes positively to the reduction of workplace hazards, particularly in the context of a comprehensive hazard reduction program. A recent comprehensive literature review by NIOSH reported: "Findings here were near unanimous in showing how training can attain objectives such as increased hazard awareness among the workers at risk, knowledge of and adoption of safe work practices, and other actions that improve workplace safety and health protection." (Cohen and Colligan 1998)

SUMMARY AND EXPLANATION OF THE RULE

Chronology of rule development

L&I began the rule development process in October 1998. Before drafting the proposed rule, L&I actively engaged the business, labor and health professional communities in detailed discussions. These discussions included nine public rule development conferences around the state in late 1998, which were followed by the work of two advisory committees in the first half of 1999. These activities were followed by numerous informal discussions with employer and employee organizations. Fifteen key ideas emerged from these discussions and guided the development of the proposed rule. (Table 6)

After the proposed rule was issued there were fourteen formal public hearings in seven cities around the state. Two hundred forty nine witnesses testified. L&I received more than 850 written post-hearing comments.

The department's objective was to develop a rule that would be fair, feasible and flexible. The final rule meets these objectives in the following manner:

- Fairness: The rule applies to all industries and all size workplaces, but specific employers are only covered where defined exposures are found. Workplaces without these risk factors are not covered. All exposed employees, therefore, receive equal protection without creating unnecessary burdens for employers. In addition, employers may rely upon their reasonable determinations as to whether they are covered by the rule.
- Flexibility: The rule requires that worker exposures be reduced below hazardous levels, however it leaves employers the choice of how to do so. For example, employers may choose the criteria used for defining hazards, the methods used for determining whether hazards are present, the methods used for reducing hazards, and the methods chosen for employee participation.
- Feasibility: Employers are required to reduce worker exposures below hazardous levels or to the degree that is economically and technologically feasible.

Explanation of the rule

Design of the rule: principles

The rule is built on the well-established occupational safety and health principle of preventing injuries by identifying and reducing worker exposure to hazards. The ergonomics rule defines two levels of exposure to certain physical risks: a) those that require caution and a more thorough evaluation to determine whether they are hazardous; and b) those higher levels that constitute hazards and require abatement. This structure is similar to that of other WISHA health standards.

Table 6
Incorporation of Ideas From Advisory Committees and Rule Development Conferences Into the Ergonomics Rule

Key Idea	Rule Provisions
The rule should be short and written in a clear, easy-to-understand format.	The requirements of the rule take fewer than 10 pages. The rule provides employers with a quick assessment of whether they are covered by the rule. It uses plain language and a clear sequence of requirements.
The rule should be based on the principle of prevention. It should be designed to prevent injuries by finding and fixing hazards.	The rule is built upon the identification and correction of risk factors before injuries occur, and it in no way relies on injuries as a "trigger" or a measure of an individual employer's compliance.
The rule's goal should be to eliminate or reduce hazards for work-related, non-traumatic, soft tissue MSDs, such as carpal tunnel syndrome, tendinitis, low back disorders, and rotator cuff syndrome. The rule should not address injuries from slips, trips, falls, motor vehicle accidents, or being struck by or caught in objects. The rule should not address non-work causes of injury.	The rule and the risk factors included in it focus on WMSDs such as those described. It does not address injuries from slips, trips, falls, motor vehicle accidents, or being struck by or caught in objects. The rule addresses risk factors only when found at work and does not address non-work causes of injury.
The rule should not address the medical management of work-related injuries and should not affect workers' compensation practices.	The rule does not address medical management and has no effect on the adjudication of workers' compensation claims.
Employee involvement should be an essential element of the rule	Employee involvement is required, including analysis of caution zone jobs, selecting control measures and the annual review of the employer's ergonomics activities.
In workplaces where there are only minor risks related to MSDs, employers should not be required to do as much as employers whose workplaces have significant hazards. The rule should not cover workplaces, job or tasks that pose very small risks.	Employers with workplaces having only very minor risks will not even have "caution zone jobs" and are not covered by the rule or its requirements. Employers with moderate risks will be required to provide ergonomics awareness education and further analyze the job to ensure there is not a higher level of risk. Only those work activities involving hazards will require changes under the rule.
The rule should recognize that finding permanent solutions to fix some hazardous jobs could take time. It should acknowledge that some potential solutions might not be economically or technologically feasible.	The rule does not require even the largest employers in the highest risk industries to correct any hazards until July 1, 2003. Depending on size and industry, other employers may have until July 1, 2006 to correct the hazards. And even following those extended periods, the rule only requires that hazards be eliminated to the extent technologically and economically feasible.
The rule should allow basic awareness education to be "portable."	The rule explicitly allows such "portability."
Record keeping and paperwork requirements in the rule should be limited.	The rule does not require any particular records, nor a written program of any sort. Employers may choose to demonstrate compliance in any number of ways, and those demonstrations themselves do not necessarily require written records.

Table 6 continued

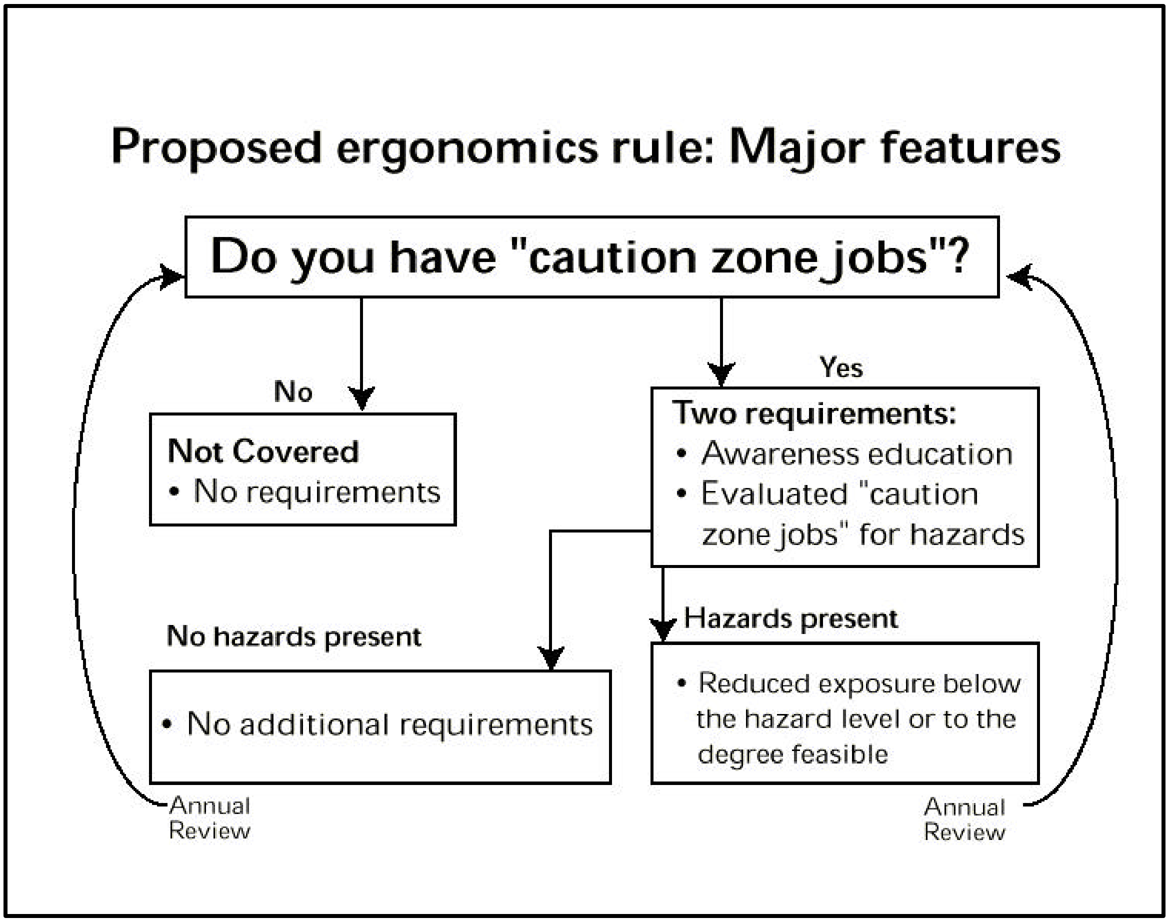
Key Idea	Rule Provisions
Existing ergonomics programs that meet the basic requirements of the proposal should be considered "in compliance."	Existing programs that meet the basic requirements of the rule will be considered "in compliance" and such employers will not be required, for example, to repeat job hazard analyses done before the rule was adopted.
Delayed enforcement provisions should be part of the implementation plan to allow time for employers and employees to learn what the rule requires, try things out, and come into compliance before each element of the rule is enforced.	The rule provides no enforcement at all until July 1, 2002, and no enforcement for failure to correct hazards until July 1, 2003. Many employers, especially the smallest employers in less hazardous industries, will have much longer. The rule also provides for the department to evaluate enforcement practices and protocols by working with a variety of demonstration projects.
The development of industry-specific "best practices" should be encouraged as part of the implementation plan. These practices should be viewed as acceptable "safe harbors" but should not be a required part of the rule.	The development of such practices is explicitly encouraged by the rule, and initial work has already begun in several industries.
The implementation plan should include comprehensive training for L&I inspectors and consultants on the new rule. Regional workshops and site visits should also be offered before enforcement begins to give employers and employees an opportunity to learn how the rule would apply to their particular business. The department should establish policies and procedures for inspections and enforcement prior to the first effective date.	Regional inspectors and consultants will receive their first training on the new rule within the first month after its adoption, and more than two years before any employer is subject to any enforcement. Consultants will receive additional training and be readily available to present workshops and provide on-site consultations to employers working to come into compliance with the rule. The department will establish enforcement policies and protocols before the first requirement takes effect, and will discuss those policies with industry and labor groups before they are finalized.
Small business resource concerns should be taken into account in the rule and implementation plan, including the need for small businesses to have more time than larger businesses to comply. The implementation plan should allow small businesses to take advantage of methods and controls used by larger firms that comply earlier.	Even in the highest risk industries, businesses with fewer than 50 FTEs have three years before any requirements take effect and four years before they must fix hazards. Larger employers in those industries have two years before any requirements take effect and three years to fix hazards. In other industries, employers with 11 to 49 FTEs will have four years before any requirements take effect and five years before hazards must be fixed, while employers with fewer than 11 FTEs will have five years before any requirements take effect and six years before hazards must be fixed. Not only can small businesses take advantage of the experience of larger businesses in their industries, the rule itself provides a "specific performance option" that can be used by smaller employers to do much of the analytical work required by the rule.
The rule should not impose a one-size-fits-all approach. The rule should strike a balance between general performance-based elements and specific criteria so that the requirements are flexible, and yet employers and employees will know clearly what to do.	The rule does not prescribe any particular solutions. Instead, it provides two performance-based options. The general performance approach provides greater flexibility for those employers who desire it. The specific performance approach provides more detailed guidance for smaller employers who need it (but still provides a good deal of flexibility in identifying actual solutions).

The rule relies upon employers to make a reasonable determination as to whether they have any "caution zone jobs" in their workplaces, as defined by specific criteria. This determination is similar to that expected by other health standards, such as the bloodborne pathogens standard (WAC 296-62-08001), and the rule creates no obligations for employers not covered by it. For covered employers the rule functions in the same way as many other health standards that rely on initial monitoring to determine whether exposures are above the action level. "Caution zone jobs" are therefore analogous to "action levels" in other WISHA rules such as the inorganic lead standard (WAC 296-62-07521) or the cadmium standard (WAC 296-62-074). Employers with caution zone jobs are not required to reduce exposures, but to inquire further as to whether ordinary, foreseeable employee tasks involve hazardous exposures. The obligation to inquire further is similar to that imposed by other health standards to conduct representative monitoring if exposures exceed the action level. If hazard analysis shows jobs above the levels established in Appendix B or other hazard criteria established by the employer, abatement action must be taken to reduce exposures to below the hazardous level. Thus, like other health standards, an employer's duty to abate is not triggered until exposures rise above levels determined to be hazardous and requires only those controls necessary to bring exposures below hazardous levels. "Hazards" in this rule are analogous to "permissible exposure limits" (PELs) in the lead, cadmium and many other WISHA rules. The ergonomics rule also incorporates several other major features common to other WISHA safety and health rules (e.g. bloodborne pathogens, WAC 296-62-08001; mechanical equipment, WAC 296-24-21501; and fall protection, WAC 296-155-245). These features include awareness education for employees in caution zone jobs; employee participation; and a preferred hierarchy of controls.

Summary of the rule's key elements (Figure 4):

1. The rule applies only to employers with "caution zone jobs," those where any employee's typical work includes physical risk factors specified in the rule. "Caution zone jobs" are not prohibited and they may not be hazardous.
2. Employers with "caution zone jobs" must ensure that employees working in or supervising these jobs receive ergonomics awareness education. These employers also must analyze the caution zone jobs to determine if they have hazards.
3. Employers may choose their own method and criteria for identifying and reducing WMSD hazards or may use the department's specified criteria.
4. If jobs have WMSD hazards the employer must reduce exposures below hazardous levels or to the degree feasible.
5. Employers must provide for and encourage employee participation in activities required by the rule.
6. An extended implementation schedule based on industry type and employer size allows employers, especially small businesses, ample time to prepare for compliance.
7. The department will establish Demonstration Projects with employers and employees to test and improve ergonomics guides and models, industry best practices, and inspection policies and procedures as they are developed.
8. Employers may continue to use methods of reducing WMSD hazards that were in place before the rule adoption date as long as the methods, taken as a whole, are as effective as the requirements of the rule.

Figure 4



Each section of the rule is described below, along with an explanation of what the requirement means, as well as alternate provisions that were considered and rejected. A detailed listing and explanation of changes L&I made between the proposed and final rule is provided in Appendix C. A full listing of public comments and L&I's responses is provided in Appendix D.

WAC 296-62-05101 What is the purpose of the rule?

The rule is designed to prevent injuries by requiring employers to identify and reduce employee exposure to hazards that can cause or aggravate work-related musculoskeletal disorders. Some comments favored an injury-based rule where employer requirements would be triggered by the occurrence of WMSDs or symptoms in a workplace. The hazard-based approach was adopted instead of the injury-based alternative because:

- Preventing injuries is a more effective way to protect employees from harm than addressing hazards after injuries occur.

- An injury-based rule would be a significant departure from other hazard-based WISHA standards without reasonable justification.
- An injury-based rule would stimulate disputes about injury causation that would detract attention and resources from the intended focus of finding and fixing hazards.
- An injury-based rule might foster under-reporting of some injuries and over-reporting of others.
- WMSDs are often cumulative in nature. Therefore, if requirements were triggered by the report of an injury, an employer with transient employees or high turnover might face obligations arising from injuries caused at previous workplaces under the control of other employers.

Compliance with the rule will reduce the occurrence of those WMSDs caused or aggravated by exposure to the hazards covered by the rule. The rule will not reduce or eliminate all MSDs among employees. For example, it is not designed to reduce MSDs caused or aggravated by workplace slips, trips, falls, motor vehicle accidents or being struck by or caught in objects. L&I considered and rejected a rule that would cover these hazards because they are already covered, at least in substantial part, by existing WISHA rules. Also, the rule will not reduce MSDs caused by some important unregulated workplace hazards such as whole body vibration, pushing or pulling. L&I considered and rejected a rule covering these hazards because this would have resulted in requirements for measuring exposures (such as the use of complex scientific instrumentation) that would have made the rule substantially more difficult to understand and use. Finally, the rule will not fully eliminate MSDs with multiple causes that include exposure to risk factors off the job. L&I rejected the suggestion that non-work risk factors be regulated because this would have gone beyond statutory authority.

Some comments suggested that the rule be limited to hazards causing WMSDs that appear slowly but not those that appear suddenly. Others suggested that the only regulated hazards should be those that could be described as “repetitive” or “cumulative.” L&I rejected these alternatives because the terms and concepts were either too vague or based on incorrect presumptions about injury causation. For example, daily exposure to heavy, frequent or awkward lifting may cause a serious low back problem that appears slowly over an extended period of time and cannot be associated with any specific lifting task. The same daily, accumulation of physical stresses may result in a low back problem that appears suddenly following one particular lift. The rule is intended to address both situations. Limiting the rule to hazards characterized as “cumulative” or “repetitive” or WMSDs characterized as “chronic” or “gradual” would have created unnecessary confusion and would have reduced protection.

Some comments suggested that this rule should include requirements for medical management and income protection (work restriction protection) for injured workers. These alternatives were rejected for two reasons. First, L&I agrees that fully comprehensive ergonomics programs include secondary and tertiary prevention (medical management of injured workers, including early diagnosis and treatment, rehabilitation and return to work services) as well as primary prevention (preventing injury by finding and fixing hazards). However, L&I has discretion to limit the scope of rulemaking and decided to focus on the need for primary prevention. Since the purpose of work restriction protection is to induce full and uninhibited participation in medical management services and the rule does not include medical management, L&I concluded that work restriction protection was not necessary. Second, while L&I believes there are shortcomings in the existing systems for medical management and income protection for injured workers, the issues are sufficiently complex and controversial to warrant consideration in separate proceedings. This rule does not supercede or otherwise change the Washington State workers' compensation system. Compliance with this rule and the existence or absence of caution zone jobs or hazardous jobs will not be used as the basis for accepting or rejecting a workers' compensation claim. L&I will continue to adjudicate claims based on the legal definitions of workplace injury and occupational disease as reflected in the statute and interpreted by the courts.

WAC 296-62-05103 Which employers are covered by this rule?

This rule applies to all industries and all workplaces, without regard to size, within L&I jurisdiction under the WISHAct (RCW 49.17). However, specific employers are covered only if they have workplaces with "caution zone jobs." Coverage was defined this way for three reasons. First, many employers asked for a clear and simple way to determine whether they were covered. Second, L&I considers many exposures to physical risk factors to be low enough that regulatory attention would be unnecessary and excessive. Third, this design is consistent with the initial determination required under many other standards as to whether occupational exposures exist and whether they exceed an action level sufficient to trigger other requirements.

Some comments suggested that all employers in the state be required to establish ergonomics management programs regardless of the presence of specific risk factors. The rationale for such an approach is that WMSD risk factors are sufficiently widespread to require all employers to provide education to all employees and to proceed directly to the analysis of jobs for hazards without any intermediate steps. L&I rejected this alternative because the best available evidence, including the L&I employer survey (Foley, 1999), indicated that a substantial number of employers have workplaces with minimal exposure to physical risk factors or only a small number of jobs with risks. L&I concluded that it would be unreasonable to require all employers to establish a program and decided to impose requirements only where risk can best be demonstrated.

Some comments suggested that the rule exempt employers in certain industries such as construction, agriculture, and maritime or those operating small businesses. This was based on concerns such as the difficulty of providing education and other requirements for a transient or seasonal workforce, the difficulty of controlling some WMSD hazards in outdoor or highly "changeable" environments, the belief that certain industries have few meaningful hazards, or the regulatory burden for employers who have limited resources. The department chose not to exempt these employer groups from the rule for the following reasons:

- The hazards for WMSDs are widespread and a large number of employees would not be protected if entire industry groups or workplace sizes were exempted. The WISHAct requires safe and healthful working conditions "insofar as may be reasonably possible" for "every man and woman working in the State of Washington." L&I concluded that it is possible and reasonable to provide equal protection to all employees exposed to WMSD hazards by designing a rule which limits employer requirements to those circumstances where employees are actually exposed. The rule design takes into account that there are many workplaces with only few employees at risk and that there are industries that on the whole have relatively few high risk jobs. In these workplaces and industries employers must only address the risks that are actually present, thus providing equal protection to employees while preserving fairness for employers.

- Many other WISHA safety and health rules apply broadly to all industries and all size workplaces, but impose requirements only where there is hazardous exposure. For example, the bloodborne pathogen standard "applies to all occupational exposure to blood or other potentially infectious materials." (WAC 296-62-08001)
- The rule takes into account the limited resources of smaller employers. A phased-in implementation schedule allows most of the smallest employers the maximum length of time (up to 6 years) to control WMSD hazards. Even in the highest risk industries, small employers would have up to 4 years to control WMSD hazards. The phased implementation schedule also allows small employers to take advantage of methods and controls used by larger firms that comply earlier. L&I has also developed an implementation plan, intended particularly for small businesses, to collect and share the most effective examples of ergonomics training, job analysis, and specific controls.
- The rule recognizes that there are substantial differences among industries with regard to the way work is organized and the options available for solving problems. While L&I has established one ergonomics rule for all industries, the rule itself is flexible enough for vastly different employers and industries to adapt it to their particular circumstances. For example, the rule establishes a performance requirement for reducing exposure to hazards and provides a flexible choice of methods for reducing exposure to these hazards without prescribing any specific abatement methods. Also, the rule allows employers the choice of using L&I's specified criteria for evaluating hazards or developing criteria that better meet the employer's needs.
- The rule takes into account the special needs of employers who have businesses with transient workforces and temporary worksites. For example, ergonomics awareness education is portable and can move with an employee. The employer, another employer, or some other organization could provide the awareness education.

WAC 296-62-05105 What is a "caution zone job?"

This section defines "caution zone jobs" and therefore provides employers with a way to determine whether they are covered by the rule. Employers must determine whether they have jobs meeting any of fourteen specific caution zone job criteria. The caution zone jobs all have a sufficient degree of risk to require some modest cautionary steps (awareness education and job analysis) but they do not necessarily have risks great enough to require corrective action. Employers without caution zone jobs do not need to comply with any requirements of this rule. The caution zone jobs are not prohibited.

L&I believes there is a firm scientific foundation for the choice of the specific levels of exposure that define the caution zone jobs. "Many of the factors used to identify the 'caution zone jobs'…in the Washington State Proposed Ergonomics rule were clearly identified in the NIOSH review as having substantial evidence for their role in contributing to work related MSDs."

(Rosenstock comments) The scientific evidence and reasoning used by L&I is presented below in Table 7.

L&I recognizes there are some work activities that might meet the caution zone criteria but occur so infrequently that workers are at minimal risk. Therefore, jobs with the specified physical risk factors are not considered caution zone jobs unless the work activity meets the additional test of being "typical work" for employees. This means that the caution zone criteria are met more than one day per week and more often than one week per year. This addresses the concern expressed by some comments that the caution zone criteria should take into account that recovery periods allow the body to readjust following stress and can effectively reduce the risk from some exposures.

L&I intends that every employee doing a caution zone job be identified, that each such employee receive basic awareness education, and that each such job be further analyzed. However, L&I also recognizes that in many workplaces more than one employee may do identical or essentially the same jobs. It is not expected that employers will do a separate caution zone analysis for every employee on every shift on every day. Representative sampling of very similar jobs may be used. For example, if thirty employees use identical wire strippers for the same repetitive task, the employer may assess how several workers do the job rather than all thirty. While employers may choose to use representative sampling they should design the sampling strategy carefully and appropriately. For example, a different sampling method might be needed for risk factors influenced by the size of individual workers. A short worker on a particular job may work with his or her hands above the head while a taller worker might not. Choosing several average size workers for representative sampling would not be sufficient to identify those workers in the caution zone. An alternate, more effective approach might be to evaluate the postures used by the workers at the two extremes of size as well as the average or midrange.

L&I will not require employers to observe employees for full work shifts to determine whether caution zone limits are reached. It is permissible to observe typical periods of work and calculate or estimate what the full day exposure would be as long as there is a reasonable basis for believing that the period of observation is representative. For example, consider a job in which an employee performs the same five-minute sequence of work repetitively for six hours every day and two minutes of each five-minute sequence (or 40%) is spent inspecting parts with the neck bent. The employer could observe several work cycles and then calculate that 40% of six hours or 2.4 hours is spent with the neck bent. It is also permissible to rely on previous knowledge, evidence established for other purposes (e.g. time motion studies or job safety analysis), or job descriptions instead of direct job observation as long as there is a reasonable basis to believe that such information or knowledge is accurate, representative and sufficiently detailed. Production data could be used to estimate the number of lifts per day for materials handling jobs. If the employer has intimate knowledge of regular work activities, duration of exposures may be estimated with or without direct observation of the work. Where regular work activities are not well known to the employer, worker interviews can be used to identify typical work. The employer could then observe relatively short sample periods of actual work to validate the interview information.

Some employers, particularly those with non-fixed worksites, expressed concern about evaluating jobs with intermittent, unpredictable or highly variable tasks.

> "Public works employees perform a large variety of tasks on a regular basis. These tasks vary frequently, often on a daily or weekly basis." (Edwin Ivey, City of Longview)
>
> "In the construction industry, working conditions are constantly changing. A worker may be on his knees doing pre-assembly of duct one minute and be on a ladder with his hands over his head mounting that duct to a roof truss the next." (Terry Poe, All Seasons Heating and Air Conditioning, Inc.)
>
> "In the waste management industry, the vast majority of workers are employed at constantly changing non-fixed work sites…" (Gordon Walgren, Washington Refuse and Recycling Association)
>
> "Our maritime industry is unique. The workforce is comprised of casual labor that is dispatched to many different jobs via the contractual joint dispatch procedures. Thus, we cannot determine who will take any particular job on a particular day. A worker may take a job driving a semi tractor one day, and then elect to take a job putting twist locks into a container as it is lifted aboard a ship the next." (Rob Bohlman, Jones Stevedoring Co.)

Ergonomic hazard analysis of variable jobs is similar to the analysis of fixed jobs. Whereas fixed jobs have one (or a few) tasks that are evaluated for the presence of risk factors, variable jobs typically have a larger number of tasks that must be identified and evaluated. The risk factors present will likely vary in intensity between the different tasks. The evaluator will have to add up the total time contribution, or frequency contribution, as required for the different tasks, to determine whether the limits listed in the caution zone table, or in Appendix B, can be reasonably expected to be exceeded during "typical" performance of the job over time. Extremely precise measurements of task times or frequencies are not required for comparison with caution zone and Appendix B limits. Reasonable accuracy, and clear, sensible, means of determining the results, will be the primary factor determining the acceptability of the analysis.

Caution zone determination for a variable job consists of the same two steps that are performed for fixed jobs:

- First, it is necessary to identify or list the different "typical work activities" that are part of the various tasks performed by the worker(s) doing a given job. Where this initially is not well known to the employer, this can be accomplished by observing worker(s) performing the tasks and/or by asking worker(s) to identify the different tasks they perform. It is important in this first step to determine all the major tasks typically performed by the worker(s) as a routine part of their overall job over time, including tasks that vary from day-to-day. In workplaces where several different workers perform essentially the same job, a separate caution zone analysis does not need to be performed on all workers, on all work shifts, on all days. A representative sample of workers performing the same job should be observed performing the tasks, including workers of different sizes (e.g. short, average and tall heights) where such individual differences might affect the outcome of the caution zone risk factor analysis. One or more workers can be interviewed to help identify the range of tasks they perform and to help estimate the approximate percentage of their time spent performing the various tasks (this can be per day, per week, per job, or whatever measure is appropriate for this job).

- Second, determine whether the job qualifies as a "caution zone job". The tasks identified in step one (for this job) are analyzed to determine whether they include one or more of the specific physical risk factors listed in the caution zone table, and whether the risk factors(s) for this job qualify the job as a caution zone job. Hazard contribution times from the different tasks are "added up" to make this determination. Where this information is not readily available to the employer from past/present knowledge (e.g., from existing job descriptions, time motion studies, job safety analyses, production data, etc.) it must be determined. One way to determine the hazard contribution from one of several tasks would be to determine the percentage of the overall job time that is spent performing this one task, and then determine the percentage of time during that task that the worker is exposed to the ergonomic risk factor. For example, a task done for four hours that involves working with the hands above the head only ¼ of the time results in an awkward posture risk factor duration (for that one task) of 1 hour per day. Similar calculations are done for all the other task components of the job, and for each risk factor that is present. The calculation can be done for a day, a week, the duration of the job, or whatever interval is appropriate for that particular job. For comparison with the limits specified in the caution zone table, the total risk factor exposure numbers should be converted to a daily basis.

Typical work activities have been defined as those that are a regular and foreseeable part of the job and occur on more than one day per week and more frequently than one week per year. L&I's intent is to limit caution zone jobs to those that expose employees to risk factors regularly rather than infrequently. However, when applying this notion of frequency to highly variable jobs it is important to distinguish between work activities and tasks. For example, consider a job that involves ten different tasks, each one of which is done for less than a day each week and each one of which involves exposure to high hand force. For this job, although each task is infrequent, the work activities involving the risk of high hand force do occur frequently and must be counted in the job analysis. Where the job involves performance of a very large number of tasks, it may be possible to group similar physical tasks, or chose a subset of the large number of tasks as representative of all the tasks. Again, a reasonable representation of the tasks involved in job performance is what is required for the analysis.

More formal job analysis methods have been developed with non-fixed worksites in mind and are available for use by employers that chose to use them. These include OWAS (Mattila 1992), ARBAN (Wagenheim et al. 1986) and PATH (Buchholz et al. 1996). These methods were developed originally for use in the construction industry but have been applied in a wide variety of non-fixed work environments. They each first determine the tasks likely to be done and estimate the amount of time spent in that task. They then analyze risk factors by individual tasks and sum up the total levels for the job based on estimates of time spent in each task. Each of these methods has been used widely and is available in either computer-based or paper format. Workgroups of industry representatives, labor representatives and technical experts have found it useful to apply these methods, particularly for the evaluation of a whole industry or group of companies. In the construction industry, an existing report on tasks and risk factors by Everett (1997) has proven to be a helpful start for such a workgroup. It would be possible for contractors and workers to compare the risk factors by task and subtask identified by Everett and apply them to the duration of exposure expected for the task. These generic assessments could be modified as necessary for unusual circumstances.

Some comments have requested clarification regarding the proper way to measure the duration of time an employee is exposed to a risk factor. L&I agrees that the proposed rule was not sufficiently clear and has stated explicitly in the final rule that duration in hours per day refers to the total time of exposure to the specific risk factor, not the time doing the work activity that includes the risk factor. For example, if an employee is moving his hand above and below his head repeatedly for three hours but the actual amount of time with the hand held above the head is just twenty minutes, the duration at risk is considered twenty minutes rather than three hours.

Some comments expressed concern that the caution zone definitions are so specific that employers may be arbitrarily held accountable for trivial violations by unreasonable, inflexible inspectors. Some have suggested that it will be necessary for employers to become excessively meticulous about measuring exact angles or timing tasks to the second in order to be certain they are in compliance. L&I established precise caution zone criteria in response to other employers who argued convincingly for clear, specific definitions and employers who clearly fall outside the caution zone are therefore protected against arbitrary or inflexible enforcement. While specificity is preferable to vagueness for employers who want to know with certainty whether they are covered by this rule, L&I believes it would be counterproductive to apply these criteria in an overly rigid way. Therefore, the rule makes it clear that employers are required only to make a reasonable determination as to whether they have caution zone jobs. If an inspector and an employer have similar, but different judgments (for example about the duration of exposure or the angle of a bent wrist), the agency will defer to the reasonable judgment of the employer.

WAC 296-62-05110 When do employers' existing ergonomics activities comply with this rule?

This section permits employers to continue ergonomics activities differing from the requirements of this rule if they were in effect before the adoption of this rule and, when taken as a whole, are as effective as the rule's requirements in reducing WMSD hazards and providing employee education, training and participation. While L&I intends this section to allow a variety of different approaches, a program will not be in compliance unless it is based on the recognition and control of hazards and unless (except as noted below) it establishes specific criteria for hazard reduction. If a program uses the report of an injury to trigger job evaluation and control, it will not be in compliance unless it also evaluates jobs for hazards independently of injury reports. If a program establishes overly vague criteria for defining a hazard (such as "awkward postures" or "heavy, frequent lifting" without specific definitions) it will not be in compliance. On the other hand, it may not be necessary to establish a specific hazard definition if the control criteria would inherently encompass any reasonable definition of a hazard. For example, a program that reduced all exposures of the types covered by the rule "to the lowest level feasible" would be consistent with the hazard identification and control provisions of the rule, even though specific criteria for hazard levels had not been established.

If an employer has already evaluated some or all jobs for hazards prior to the adoption of this rule, the employer is not required to begin the job analysis process over again. Likewise, if an employer has provided basic ergonomics awareness education prior to rule adoption, the employer would not have to begin again.

Some employers have suggested that employers be in compliance if they have acted "in good faith" to reduce WMSDs. "If an employer is making a good faith effort to identify, prioritize and correct hazards, the Department should not substitute its judgment for that of the employer unless the Department can show, to a substantial certainty, that its proposed corrective action will result in greater reductions of injuries." (PJ Edington, Center for Office Technology comments) L&I has decided to reject this suggestion for the following reasons: First, the effectiveness of employee protection should be measured against the employer's actual performance in reducing hazards, not the employer's intent. An employer who in good faith fails to acknowledge serious hazards that are recognized by most other employers, perhaps because he or she does not believe that ergonomics has a sound scientific basis, should not be deemed in compliance. Second, the "good faith" formulation would require an inquiry into the employer's state of mind and not an objective inquiry into whether the program was effective or reasonable. Since inspectors are not equipped to judge an employer's beliefs or intent, this provision would be difficult to enforce in a consistent or predictable manner.[40] Third, the requirement for the Department to prove its assertions "to a substantial certainty" would establish a burden of proof substantially higher than the more typical "preponderance of evidence." Allowing "good faith" to trump any evidence that fell short of "substantial certainty" would frequently err on the side of underprotection of workers. Fourth, the proposal would render the rule less protective than the existing general duty of employers to use all feasible controls to keep workplaces free from recognized hazards. Under the existing safeplace standard (WAC 296.24.073) employers must do everything that is reasonably adequate and necessary to control recognized hazards. "Good faith" might not result in reasonably adequate and necessary controls. Under UAW v General Dynamics, any standard that relieves an employer of its general duty obligation is improper.[41] Fifth, the Legislature has considered the concept of "good faith" and determined that it is an appropriate consideration in the determination of penalty amount when standards have been violated but not whether a standard has been violated (RCW 49.17.180(7)).

WAC 296-62-05120 Which employees must receive ergonomics awareness education and when?

This section establishes that every employee in a caution zone job and the supervisors of these employees must receive basic awareness education as described in the implementation schedule. After this date, employees and their supervisors must receive the education within thirty calendar days of assignment to the job unless they have received it within the previous three years.

[40] WISHA inspectors are expected to consider "the good faith of the employer" when calculating penalties after violations of safety and health standards have been cited. The WISHA Compliance Manual (7/1/99) instructs inspectors to make this determination based on "the employer's demonstrated efforts" rather than a judgment about belief or intent. The elements of this determination include the employer's awareness of the Act, whether efforts were made to comply before the inspection, whether the employer promptly abated violations during the inspection, cooperation and attitude during the inspection, and the employer's overall efforts.

[41] UAW v General Dynamics, 815 F.2d 1570 (D.C. Cir. 1987)

Employers are not required to provide this education, but to ensure that employees have received it. This means that the education is "portable." It could be provided by previous employers, trade associations, labor unions, community colleges, apprenticeship programs, universities, private consultants, or other sources. L&I intends to provide model education programs in written, video and interactive formats. Employers using or relying upon model education materials provided by L&I will be deemed to be in compliance. As with other provisions in this rule, employers are not required to keep written records but they must be able to demonstrate compliance. Acceptable methods of demonstrating compliance include, but are not limited to, signed class rosters, verbal demonstration from employees of successful education, certified training cards from a recognized program or signed statements documenting completion of interactive educational programs.

WAC 296-62-05122 What must be included in ergonomics awareness education?

L&I intends that the ergonomics awareness education will provide employees with a basic level of understanding and knowledge rather than thorough and detailed expertise or competence. The rule specifies the general subject matter but not the specific content. These subjects include the causes of musculoskeletal disorders (including the risk factors covered by the rule), the nature of WMSDs and the importance of early reporting, ways to identify hazards and common measures to reduce them, and the requirements of the rule. L&I expects that adequate education could be provided in one hour, although somewhat shorter programs might be adequate if well designed and delivered. L&I encourages longer periods of education, but the rule does not require this.

The rule does not require a specific format for the awareness education, nor does it express a preference. Acceptable methods would include, but are not limited to, classroom education with an instructor, video presentations, interactive CD or Internet modules, or written instructional materials. A brochure, leaflet, or fact sheet without additional instruction or opportunity for discussion would not generally be acceptable, because it would not provide effective education. L&I considers it important that employees have an opportunity to ask questions and have them answered.

The proposed rule required that the awareness education address the specific risk factors present in the job to which the employee is assigned. Some comments suggested that employers and employees would find it excessively difficult to keep track of the match between specific jobs and specific educational modules over a three-year period. Therefore the final rule has been modified to require that the education for all exposed employees, regardless of specific job assignment, address each of the six basic groups of caution zone risk factors. This makes portability more practical.

The ergonomics awareness education is a general requirement for all employees on caution zone jobs. It is not a requirement for training on the hazards and controls for specific jobs. The rule includes a separate, additional training requirement limited to those employees working on hazardous jobs when measures are taken to change the job or work practices.

WAC 296-62-05130 What options do employers have for analyzing and reducing WMSD hazards?

This section requires employers to analyze caution zone jobs to identify those with WMSD hazards that must be reduced. It defines WMSD hazards, establishes acceptable methods of analysis, requires that WMSD hazards be reduced and describes acceptable measures for reducing hazards.

This section provides employers a choice between a specific and a general approach for identifying and reducing hazards. This choice was provided to accommodate the different but equally legitimate needs expressed by two groups of employers. Some, especially small employers with limited resources, emphasized the need for specific requirements that provide maximum clarity and certainty. These employers were willing to forgo some flexibility in order to achieve certainty. Others, particularly larger employers with more resources, requested general requirements that provide more flexibility. These employers were willing to forgo certainty in order to achieve greater flexibility. L&I believes there is merit to both approaches, but that each one alone would be too constraining and would fail to meet the needs of many employers.

Whether employers choose the specific or general approach, they are required to analyze caution zone jobs to determine if they exceed exposure levels defined as hazardous. For the specific approach these hazard levels are stated in Appendix B. Those choosing the general approach may establish their own hazard levels as long as they select criteria similar to and at least as effective as the recommended levels in other methods achieving wide use and acceptance around the country. Several examples are provided, each of which incorporate recommended control levels that identify those physical risk factors that have a sufficient level of intensity, duration or frequency to cause a substantial risk of WMSDs and are considered WMSD hazards. While employers choosing the general approach are not limited to these specific methods, they also are not free to adopt any widely used method, but only those that effectively protect employees from physical risk factors that are likely to cause a substantial risk of WMSDs.

Employers using either the specific or general approach must analyze the caution zone jobs in a thorough and systematic manner to determine if the hazard criteria have been exceeded. This means paying attention to the physical demands of the job (such as posture, force, and repetition), the layout of the work area (such as reaches and working heights) and the manual handling requirements of the job (such as size and shape). This requirement for a systematic review is meant to increase the likelihood that any hazards present will in fact be identified. For the same reason employers must also ensure that individuals given the responsibility for job analysis know how to use the chosen method effectively. This performance requirement does not specify the content and duration of training.

Employers must reduce employee exposures below hazardous levels (as defined in Appendix B or the employer’s chosen alternative) or to the degree that is economically and technologically feasible. L&I intends that no employer will be unfairly burdened by the rule. Therefore, the concept of feasibility is specifically written into this rule. In doing so, however, L&I does not intend to establish new feasibility principles or tests.

In determining whether it is feasible for an employer to comply with a rule, L&I will generally consider the following factors:

- The extent to which compliance with the rule is technologically possible, and whether it precludes performance of the required work.
- Whether alternative means of employee protection are either in use or available. Availability includes means of protection that can be reasonably anticipated. It is expected that the rule will stimulate innovation.[42]
- The costs of compliance, and whether the employer can absorb or pass on the cost. Attention is given to whether compliance measures will threaten the existence of a firm or otherwise cause substantial economic damage. The nature of a business is generally taken into account, with consideration to what other similar employers have found feasible. The size of a business is also taken into account and small employers are not necessarily expected to implement costly controls that a larger employer in the same industry found feasible.

Several people requested clarification as to whether L&I would find it feasible for employers to undertake protective measures that conflict with other regulations and laws. "In many cases municipal regulation make the task even more difficult. For example, many municipalities prohibit curbside service and require backyard collection which may require the worker to haul fully-loaded garbage cans (of the customers' choosing) up or down stairs…Other municipalities institute refuse container pricing which encourages the use of large and/or very heavy containers." (Gordon Walgren, Washington Refuse and Recycling Association) In assessing such circumstances L&I would take into account whether the restrictions were imposed under the municipality's legislative authority or were embodied in a jointly agreed contract. An employer who has a contractual, as opposed to legislated, obligation to provide services in a certain way also can expect to have the opportunity to renegotiate that contract at specific times. An employer who made no effort to do so during the implementation period provided by the rule could not expect to be successful in arguing that elimination of the hazards was not feasible. However, if the employer cannot legally provide the service in a different manner due to a municipal ordinance, then elimination of the hazard would preclude the performance of the required work and it would therefore not be feasible to do so. However, any such determination would also require that the employer had implemented all other feasible controls.

This issue is not unique to the ergonomics rule. On a number of occasions, for example, employers have raised feasibility concerns based on existing language in labor-management contracts. In such cases, the department has rejected the argument because the rules establish the minimum level that must be afforded workers. Labor and management can agree to exceed the requirements of a rule, but not to violate them.

Several people requested clarification as to whether L&I would find it feasible for employers to undertake protective measures when the working environment was under the control of others. In assessing such situations, as in other multi-employer worksite situations, L&I would consider as feasible only those actions that the employer could be expected to take based on reasonably anticipated hazards and to the degree he or she controlled the worksite. For example, a company

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[42] "The oft-stated view of technological feasibility under the OSH Act is that Congress meant the statute to be "technology forcing." *United Steelworkers of America v. Marshall,* 647 F.2d 1189, 1264 (D.C Circuit, 1980) (lead).

that manufactures and delivers goods to a retail store might not be able to control hazards related to the slope and location of the ramps or awkward lifts required by the layout of the store. However, the size of product packaging and the amount loaded onto a handtruck at a given time – as well as the nature of the handtruck and whether one was provided at all – would normally be well within that employer's control and represent feasible steps. In some cases, the employer who controls the environment would also have an obligation to control the hazard. If the retail store could reasonably be expected to be aware of the hazards created by the layout of the store, for example, the store's obligation to protect employees would extend not only to employees working for the store, but also to other employees subject to the hazard.

In certain cases, employers outside L&I's jurisdiction control the hazard. The hazard may even be the result of national or international law. For example, "Our jobs and working conditions are often defined by others. Ship cargo is loaded and secured with slings and securing equipment that often travels with the vessel and is not owned by the terminal operator…This may result in a situation where the employer may not be able to implement fixes even where they may be technologically feasible. For instance, inter box connectors…are made out of cast steel. These are owned by the shipping companies. They conceivably could be made out of titanium to reduce weight….but shipping companies certainly would avoid purchasing them due to the cost." (Robert Bohlman, Jones Stevedoring Company) L&I cannot require employers engaged in handling such cargo to refuse to do so, and the shipping companies are not subject to L&I's jurisdiction. Therefore, an employer handling such cargo cannot be expected to change the size or nature of the cargo itself. However, as always, any other feasible means of reducing the hazard must be put into place.

Several questions have been raised about the feasibility of compliance in agricultural workplaces.

- Will growers be expected to hire more workers, each working fewer hours, to pick asparagus if there is no other way to do the work safely? L&I believes that most jobs can be fixed, particularly given the time provided by the extended implementation schedule. In the case of agriculture employers, no controls will be required until July 1, 2004 (July 1, 2006 for the smallest employers). If, in fact, asparagus cannot feasibly be picked in a manner that eliminates the hazard and all feasible steps to reduce the hazard have been taken, then the rule clearly states that the employer has fulfilled his or her obligation. As described in more detail below, the rule does not require employers to replace full-time with part-time employees or to otherwise reduce an individual's employment hours.
- Will L&I consider expenditures on ergonomics controls to be infeasible if commodity markets outside the grower's control set agricultural prices and the cost cannot be passed along to consumers? L&I would take into account the effect of non-discretionary increased costs in agriculture as it would for other industries. If the cost in such a circumstance could be absorbed without substantial economic damage, the employer would be required to do so. If such costs represented a threat to the business or otherwise caused substantial economic damage, the employer would not be required to absorb them and could rely on other feasible means that reduce the hazard as much as possible.

L&I recognizes that feasibility is not fixed, but changes over time. The WISHAct was meant to stimulate innovation. While employers will be expected to take advantage of some feasible measures as soon as they become known and available, it is not expected that this will always be the case. For example, suppose that a supermarket purchases the most effective checkstand for reducing a repetitive motion hazard that is feasible. This checkstand reduces the hazard by 90%, but two months later a new model becomes available that reduces the hazard 100%. L&I would not require immediate purchase of the new equipment, but would work with the employer so that implementation of better controls was consistent with the equipment changeover cycle typical for the industry.

Feasibility is normally addressed on a case by case basis. Employers are responsible for determining whether it is feasible to reduce employee exposure below the hazard levels. L&I inspectors may disagree with the employer's determination if and when there is an inspection. Where there are such differences of opinion L&I may issue a citation that is subject to employer appeal. L&I believes that it is desirable to provide guidance about technology and other solutions that are available and acceptable when possible before inspections take place. The extended implementation schedule provides an opportunity for L&I to work with employers and employees to reach common understandings about available, effective and feasible practices for hazard reduction for various types of work. Employers choosing to use such "safe harbor" guidance would be deemed in compliance.

The proposed rule expressed a preference for employers to use engineering or administrative measures to reduce hazards before methods that primarily rely on individual work practices or personal protective equipment. This concept of a hierarchy of controls is common to many WISHA standards and is based on the knowledge that personal behavioral controls and personal protective equipment are typically less reliable and often less effective than engineering and administrative controls. Some comments asked whether "preference" meant that employers were required to use engineering and administrative measures before others or merely that they consider their use first. The final rule clarifies that employers must turn to individual work practices or personal protective equipment only after feasible controls that do not rely primarily on personal behavior are found to be insufficient. In other words, feasible controls other than those relying on personal behavior must be used even if they do not fully reduce the hazard. Controls relying on personal behavior must then be used for supplementary or interim purposes. The specific examples of engineering and administrative controls and the specific examples of individual work practice and personal protective equipment are not listed in order of preference. Employers may also use individual work practices or personal protective equipment to supplement the protection provided by other controls that by themselves would have been sufficient.

While L&I believes there is an appropriate place for personal protective equipment in the prevention of WMSDs, the agency believes the scientific evidence for effectiveness is extremely limited. L&I therefore advises employers to be cautious and judicious in the use of personal protective equipment and to do so only when there is reliable evidence to support the specific use. At this time L&I does not consider back belts, back braces or wrist splints to be personal protective equipment because there is inadequate evidence that their use prevents injury. (Bulthaut 1999; NIOSH 1994)

A number of employers and employees expressed concern that the proposed rule appeared to require that employers replace full-time with part-time employees or otherwise reduce employment hours if other feasible methods were inadequate to reduce exposure below hazardous levels. It is L&I's intent to neither require nor prohibit this. The final rule clarifies that if an employer has implemented all other feasible controls and a hazard remains, the employer is not required to reduce exposures further by replacing full time employees with part time employees or otherwise reducing an employee's hours of employment. For example, suppose a masonry contractor used various engineering, administrative and other feasible measures to reduce the risk from heavy, frequent lifting but a hazard still remained. The contractor would be in compliance without being required to reduce the work hours of each bricklayer even if this further reduced the hazard. A further consideration was L&I's concern that an employee who had been reduced to part-time employment to reduce exposure to a hazard would be likely to seek other part-time employment in the same industry with exposure to the same hazard and thereby not receive any meaningful protection from this rule.

L&I also received questions regarding the replacement of workers with other means and methods. For example would replacing workers with fully automated checkstands in a grocery store be required if no other feasible means to reduce hazards were available? The rule clearly does require feasible mechanical assistance on jobs to reduce hazards in some situations when other feasible methods are not sufficient. Providing mechanical assistance to employees as they perform their duties is sometimes a preferred method of control, which may also result in improvement in efficiency and productivity. However, L&I does not intend to require pervasive or disruptive automation such as full automation of grocery checkstands.

Job specific training must be provided to an employee when there are changes in the employee's job or work practices to reduce WMSD hazards. The topics for this training are specified, but the particular details including the amount of time required and the format for the training depend upon the particular circumstances. This training is in addition to the requirement for ergonomics awareness education.

No written ergonomics program is required by this rule, although several comments asked that all covered employers be required to have one. L&I concluded that the hazard-based, performance requirements of this rule make it unnecessary for each employer to describe the general features of their ergonomics program. However, L&I also concluded that employers should be able to demonstrate that they have successfully met all the performance requirements of the rule. L&I agrees with those comments asking that the rule avoid requirements for burdensome written records to the degree possible and the rule therefore stops short of requiring specific demonstrations or documentation. While L&I anticipates that many employers will keep specific written ergonomics records, others may choose to rely on other methods, such as videotapes, photographs, receipts, or maintenance logs. Some employers may choose to document their compliance with this rule by including ergonomics in their written accident prevention program, but this is not required.

WAC 296-62-05140 How must employees be kept involved and informed?

This section establishes a performance requirement for employers to encourage and provide for employee participation in analyzing caution zone jobs and selecting hazard reduction measures, but it does not prescribe specific ways to do this. Where safety committees are required they must be involved in the choice of the methods used for employee participation. While L&I expects employers to provide and encourage meaningful opportunities for employee involvement, this rule does not change in any way the employer's responsibility and authority for making decisions about how to comply with this or other WISHA rules.

This section also requires employers to share certain information with safety committees or at safety meetings. Employers must also review their ergonomics activities for effectiveness and any needed improvements and must ensure employee involvement in this review through the safety committee or an equally effective means.

WAC 296-62-05150 How are terms and phrases used in this rule?

This section defines key terms in the rule that are not defined where they are used.

WAC 296-62-05160 When must employers comply with this rule?

This section provides a compliance schedule based upon employer size and industry, with high-risk and larger employers required to comply before others. No employer must comply with any provisions of the rule in less than two years from the rule's adoption date. All employers (other than new workplaces or businesses or those with significant changes to existing workplaces or businesses) must be in full compliance within six years after adoption.

The first group of employers covered by the rule are those in twelve specified high risk industries who have 50 or more full time equivalent employees in Washington State. The Washington State Department of Labor and Industries is included in this first group, although it is not in one of the high risk industries. The twelve industry groups are defined by three digit Standard Industrial Classification (SIC) codes established by the federal Office of Management and Budget. (In 2000, federal agencies that produce statistical data will adopt North American Industry Classification System (NAICS) codes and begin to phase out the SIC codes. The NAICS equivalents to the SIC codes may be used for purposes of this rule.) Employers with several types of business, products or operations may have more than one SIC code pertaining to their enterprise. For purposes of this rule an employer's SIC code is the employer's primary SIC based on hours of employment and assigned by the Washington State Employment Securities Department.

The twelve high-risk industries covered first are those with the highest prevention index rankings in the state for compensable WMSDs for the years 1990-1998. The prevention index, defined earlier, is a score that takes into account both the incidence rate and the number of WMSDs in each industry. For an industry to have a high prevention index rank it must have both a relatively high rate and number of WMSDs. L&I decided to use the prevention index for this rule because it identifies those industries where the impact of serious WMSDs is greatest and there are the greatest opportunities for prevention.

The proposed rule defined employer size by the number of employees. Some comments expressed concern that this would include certain employers who only employ large numbers of employees for short periods of time and otherwise have a very small workforce. L&I agrees that such employers are likely to have limited organizational resources similar to employers with permanently small numbers of employees. The final rule therefore defines large employers as those with 50 or more full time equivalent employees.

L&I's specific choice for the initial coverage group (twelve SIC groups and 50 or more FTEs) balances three concerns. First, these are employers for whom WMSDs have the greatest impact and the need for the most prompt intervention. Second, these are employers with the most substantial resources and the capability of early response. Third, L&I felt it prudent to limit initial coverage to a limited number of employers and employees, allowing for an orderly and limited start-up period. L&I estimates that approximately 450 employers and 120,000 employees are in the first group covered.

WAC 296-62-05172 Appendix A: Illustrations of physical risk factors

This section is only for the purpose of providing clear illustrations to assist employers in making reasonable determinations of whether caution zone jobs exist. It contains no additional requirements.

WAC 296-62-05174 Appendix B: Criteria for analyzing and reducing WMSD hazards for employers who choose the Specific Performance Approach

This section provides specific criteria for identifying exposures that are hazardous and must be reduced to the degree feasible. Employers are permitted to use this Appendix by WAC 296-62-05130 but they are not required to do so. The scientific basis for the criteria used in this Appendix are provided below in Table 8.

WAC 296-62-05176 Standard Industry Classification (SIC) Codes

This section is only for the purpose of assisting employers in determining when the various provisions in the rule cover them. It contains no additional requirements.

Specific evidence for the caution zone job criteria and Appendix B criteria

L&I used the following methodology and reasoning to determine the specific exposure levels used for defining the caution zone jobs and the Appendix B hazards: First, L&I searched the epidemiological literature for methodologically sound studies that estimated the quantitative relationship between observable workplace exposures and the occurrence of WMSDs. L&I gave the most serious consideration to studies meeting the NIOSH epidemiological review criteria for acceptable quality and sound study design. (Bernard 1997) Second, L&I identified a subset of these studies that quantified exposure in terms of frequency, duration and/or intensity (or magnitude). Third, L&I looked for exposure levels at which WMSDs began to occur and higher levels at which WMSDs became more widespread or severe. In particular, L&I identified exposure levels (or ranges) at which there was a statistically strong relative risk of at least 1.5 for one or more types of WMSDs.[43] L&I's approach to negative or inconsistent studies was described earlier. Fourth, L&I considered the evidence as a whole in a manner similar to NIOSH. "Thus these studies were not only viewed individually (taking into account good epidemiologic principles) but together as a body of evidence for making broader interpretations about epidemiologic causality." (Bernard 1997) Fifth, L&I converted these scientifically estimated risk levels into regulatory exposure levels that adequately protect workers, but also take into account the need for consistency, understandability, simplicity, and practical application. Caution zone criteria were set at levels where the risk begins to rise and caution is needed. The hazard level criteria were set at levels where the evidence for high risk is most secure. The methodology described resulted in the adoption of exposure levels that fall within a reasonable zone and are understandable to employers, protective of employees and administratively workable.

A narrative description is provided below to explain how L& I applied this methodology in its consideration of each type of risk factor and arrived at its decisions about the exposure levels specified in the rule. In addition, Tables 7 and 8 provide summary information on selected key studies relied upon by L&I in making these determinations, including industry and study type, method of exposure measurements, injury outcome and statistically significant relative risk estimates. Full copies of each study are in the rulemaking file.

Awkward postures: Hands above the head

Studies that have quantified the relationship between shoulder disorders (or neck/shoulder disorders) and overhead work, arm elevation, or extended reaches include Punnett et al. (2000); Frost and Anderson (1999, 1998); Ohlsson et al. (1995); Viikari-Juntura et al. (2000); and Holmstrom (1992). Punnett used a case-referent design to study automobile assembly workers. Cases were those reporting to the plant medical department for shoulder disorders who were then examined by the research team. Referents were age and gender matched autoworkers who had not reported to the medical department within two years for a shoulder problem. Detailed observational and video analysis was used to identify duration and frequency of exposure to 90 degrees of shoulder flexion or abduction. The odds ratios were 2.3-3.2 for exposures more frequently than once per minute, 2.0-2.6 for less than 10% of the cycle time (less than 48 minutes per day) and 3.9-6.1 for more than 10% of the cycle time in more than 90 degrees of shoulder abduction/flexion. Thus, there was increased risk with increased exposure.

Frost and Anderson conducted a cross-sectional study of meat packing workers with chemical workers as the reference population. Shoulder impingement syndrome lasting more than 3 months was evaluated by questionnaire and physical examination. Exposure was determined by questionnaire and video analysis. In this case, the exposure classification was arms raised more than 30 degrees or more than 10 times per minute compared to no shoulder elevation. Because the researchers were concerned about a potential survivor bias seen in cross-sectional studies, they also examined former workers who had the same jobs as the current meat packers. The

[43] "Relative risk" refers to the comparison of the level of risk in one group versus another. If 20% of a group of employees who lift heavy objects develop back injuries and 10% of a comparison group that doesn't lift heavy objects develops back injuries, the relative risk for lifting would be 2. Depending on the particular design of the study, relative risk might be expressed in such terms as odds ratios, prevalence ratios, risk ratios or morbidity ratios.

odds ratio for the current workers was 5.3. For the former workers it was 7.9. The risk increased with cumulative exposure years.

Ohlsson did a cross sectional study of female industrial workers in repetitive jobs compared with non-exposed referents, including physical examinations for neck and shoulder disorders. Exposure was video analyzed and classified as frequency of arm elevation of greater than 60 degrees, percent of time with arm abduction greater than 30 degrees or 60 degrees. The median frequency per hour in 60 degrees of abduction was 47 per hour for industrial workers compared to 0 for the referents, 14% of the time (more than 1 hour) at greater than 30 degrees, and 1% of the time in more than 60 degrees compared to 0%. The risk of WMSDs increased with repetitive arm elevation (OR= 3.3 for elbow and hand disorders and 4.6 for neck and shoulder disorders).

Viikari-Juntura used validated exposure assessment questionnaires and psychosocial questionnaires, including individual factors, in a longitudinal study of radiating neck pain (more than 8 days) among forest industry workers. The investigators found an OR of 1.2 for hands above the shoulder between 30-60 minutes per day, and an OR of 1.6 for more than 2 hours per day. The analytic model took into control obesity and high mental stress, which were also significant risk factors.

Kilbom (1994) has argued that repetitive shoulder movement (more than 2.5 times per minute) lasting more than one hour, particularly combined with high force, should be avoided. This was supported by a cross-sectional study of Washington aluminum smelter workers (Hughes 1997) who used physical examination to identify shoulder tendinitis and observational analysis to identify percent time in awkward postures. Carbon setters used high force in handling 20-pound steel bars to breakup crust. This required short bursts of repetitive shoulder abduction moving between external and internal rotation with high velocity and force. Controlling for individual and psychosocial factors, the odds ratio for shoulder disorders was 37.0 per year of exposure to this abduction/rotation pattern. The actual daily exposure averaged 18 minutes. The studies that relied on detailed observational exposure assessment had higher odds ratios than the studies that relied on self-reports of exposure and effect. This may be because workers tend to overestimate the duration of exposure to stressful postures, thereby underestimating the risk.

Taken as a whole, these studies demonstrate that duration of continuous or repetitive work above shoulder height increases the risk of shoulder and neck disorders, and the greater the duration or frequency of exposure, the greater the risk. All these studies support the conclusion that overhead work for more than 2 hours increases the risk for neck and shoulder disorders, although there was also some evidence for risks with exposures of less duration. Those exposed to shoulder abduction/flexion for more than four hours are at higher risk of developing neck/shoulder disorders. Holstrom (1992), for example, studied severe shoulder pain on questionnaire among construction workers in a cross-sectional study design. She found an exposure-response relationship between duration of exposure to work with hands above the head and severe shoulder pain and functional disability, OR= 1.2 for less than one hour, OR=1.5 for 1-4 hours and OR=2.0 for more than 4 hours. Thus, L&I set the caution zone level at 2 hours and the hazard level at 4 hours of cumulative static exposure or repetitive movements.

Awkward postures: Neck bent

To identify caution and hazard zone criteria for awkward postures of the neck, L&I relied on the studies of Kilbom et al. (1986); and Ohlsson (1995). Kilbom conducted a cross-sectional study of female electronics assembly workers, using video analysis to characterize exposure and physical examination to determine neck/shoulder disorders. In a regression analysis, increasing duration of the cycle spent in neck flexion of more than 20 degrees was associated with increasing severity of neck disorders. Ohlsson used video analysis and physical examinations to assess the relationship between neck disorders and neck postures in female industrial workers in a cross-sectional study, while controlling for psychosocial and individual factors. Neck/shoulder diagnoses were associated with the number of neck flexions per hour and the percent time spent in more than 15 degrees of neck flexion. In the multivariate analysis, neck flexion movements predicted neck/shoulder diagnoses. Additionally, earlier work by Hunting (1981) found an increased risk of neck disorders with neck flexion of more than 50 degrees among data entry operators.

In a laboratory study of neck flexion and severe neck pain Chaffin and Andersson (1991) found increased pain with increased duration and magnitude of neck flexion, with the vast majority of subjects unable to sustain neck flexion for two hours. In most work situations, workers are able to alter their neck posture to prevent this level of severe pain and eventual functional disability. However, in certain types of work (such as microscopic work), changes in neck posture are not possible without changes in orientation of the work.

The data in these studies on postures is stronger than that on duration of exposure. However, there is adequate information to conclude that significant pain is found with exposures to stressful postures for more than two hours and that the risk increases with duration of exposure, frequency and degrees of flexion. Therefore, L&I set the caution zone level at 2 hours for 30 degrees flexion and the hazard level at 4 hours for 45 degrees flexion principally to be consistent with this scientific data. L&I also considered it important to make the rule as simple as possible and internally consistent with the durations chosen for other regulated exposures in the rule.

Awkward postures: Back bent

Kerr (2000) found that more than 20 degrees of trunk flexion for more than 1.6 hours was associated with an increased risk of low back disorders (odds ratio=1.4). With more than 50 degrees of peak flexion the risk increased (OR=2.4). Punnett (1991) found an odds ratio of 4.2 for work with more than 20 degrees of trunk flexion for less than 10% of the cycle or shift (48 minutes) and a higher risk of 6.1 for similar work for more than 10% of the cycle. With trunk flexion of more than 45 degrees for more than 10% of the cycle the risk was still higher (OR=8.9). At least three other studies reported related findings. Vingard (2000) reported an odds ratio of 1.8 for trunk flexion more than 60 minutes a day for men, but not for women. Holmstrom (1992) reported an odds ratio of 1.3 for stooping more than four hours a day and Park (1997) found an odds ratio of 2.4 for repetitive bending or twisting more than four hours daily. This evidence, when considered as a whole, demonstrated increasing risk with increasing exposure (intensity or duration or both). There were consistently strong risks at two hours of exposure with higher risks at longer durations and some risks at shorter durations. There were also consistently higher risks with higher degrees of flexion, particularly flexion exceeding 45 degrees. To establish rule requirements that were understandable, practical and fully consistent with the scientific findings, L&I set the caution zone at more than 30 degrees of trunk flexion for more than two hours. For the same reasons it set the hazard level at more than 30 degrees of trunk flexion for four hours or more than 45 degrees for more than two hours.

Awkward postures: Squatting or kneeling

To identify caution and hazard zone levels for kneeling and squatting (awkward knee postures), L&I relied on the epidemiological studies of Cooper et al. (1994); Jensen et al. (1997, 2000); Kivimaki et al. (1992); Thun (1987); and Sandmark et al. (2000). NIOSH's review (Bernard 1997) did not include the lower extremity. The outcomes for these studies include osteoarthrosis and prepatellar bursitis. Holmstrom (1992) also found an elevated odds ratio for severe back pain for those kneeling more than four hours, although these findings were modest (OR=1.2)

Thun conducted questionnaire, physical examinations and x-ray examination of carpet layers (kneeling and repeated impact stress), tile and terrazzo setters (kneeling), millwrights (no kneeling) and bricklayers (minimal kneeling) in a cross-sectional study. For prepatellar bursitis there was an increased odds for kneeling (OR=1.8) and for knee aspirations the OR was 4.9 for kneeling. The duration of exposure was not quantified.

In a cross-sectional study, Kivimaki observed that male carpetlayers spend less than 3 hours on one or both of their knees (mostly both); whereas kneeling was rare among male painters. In Finland, where the study took place, wall to wall carpeting is rare and knee kickers are not used. Both groups spent approximately 3% of the time squatting. Comparing the carpetlayers to the painters, the OR for prepatellar bursitis was 9.5, and for degenerative changes in the vertebrae of the neck and low back was 1.3-2.4.

Jensen evaluated knee osteoarthritis among carpetlayers (not using knee kickers), carpenters and compositors in a cross-sectional study where carpetlayers spend 56% of their work time (>4 hours) kneeling or squatting whereas carpenters spent 25% of the time (>2 hours) and compositors spent no time squatting or kneeling. The OR for knee symptoms was 5.3 for carpetlayers and 2.5 for carpenters compared with controls. The OR for osteoarthritis was 2.3 and 1.3 respectively. Cooper at al. used a case-control study design among a general practice population to identify risk factors for knee osteoarthritis based on self-reports describing the job held the longest before the onset of symptoms. They reported an OR of 6.9 for squatting more than 30 minutes per day versus less than 30 minutes per day and an OR of 3.4 for kneeling more than 30 minutes per day. These studies demonstrate risk beginning with exposures of greater than 30 minutes duration, becoming clearly and consistently high with exposure duration greater than 4 hours. Therefore, based on these studies, L&I set the caution zone level at two hours and the hazard level at four hours.

High hand force: Pinching and gripping

Hand force has been defined in two ways: external forces of tasks (for example, the weight of object handled, or the force needed to grip and manipulate an object), and internal forces on body structures (for example, muscle activities of the forearm muscles). Hand force has been quantified either in absolute terms (pounds, newtons, or kilograms) or in relative terms (percentage of population hand strength or percentage of a muscle's capacity). The same external force may cause different internal force depending on postures and individual characteristics. For instance, the same external force can cause higher forearm muscle load when the hand grips the object in a pinch grip than a power grip. The same external force may also require a higher percentage of hand strength for a person with lower hand strength capacity than one with higher capacity.

Internal force is the most precise way to evaluate risk, but the impracticability of measuring it, both economically and technically, has limited its use mainly in research activities. Therefore, L&I set exposure levels for external hand force. External force (the actual amount of hand force exerted) is measured most precisely with methods like surface electromyography or instruments such as force gauges. However, because these methods are expensive, time consuming and require technical expertise they are not practical for routine workplace programs and L&I decided not to require employers to use them for evaluating exposures. Instead, the rule uses two more practical, yet reasonably close approximations of actual hand force: the weight of objects handled and the employer's ability to estimate hand forces using common reference examples.

- Weight of objects handled: Moore and Garg (1994) and Stetson et al. (1993) have all used weight of tools and objects handled to estimate hand force, taking into consideration hand postures and population strength data. The American Conference of Governmental Industrial Hygienists also recognizes weight handled as a reasonable method for estimation of peak hand force (ACGIH 2000). The hand grip force required to hold a 10-pound unsupported object ranges between 7.6 to 18.5 pounds depending on the conditions of the object surface and hand smoothness (Buchholz et al. 1988). The pinch force needed to hold a 2-pound unsupported object is 1.5 to 3.7 pounds.

- Estimates of hand force using common reference examples: During the hearings the Society of Diagnostic Medical Sonographers stated that it is possible for people to make accurate estimates of the hand force required for a task by comparing it with the force required for various common activities. Following this suggestion L&I conducted an investigation in which 120 participants were asked to pinch or grip a common object (half ream of copy paper, paper staple remover, 10 pound dumbbell, cutting a paper clip with a pair of pliers). They were then asked to match the force using a hand dynamometer (BAO 2000). The results demonstrated high accuracy and consistency (e.g. for the 2 pound pinch force, the matched force was 2.3 and 2.1 pounds for women and men respectively; for the 10 pound power grip force, the matched force was 10.3 and 9.7 pounds for women and men respectively). Kingdon and Wells have also recently completed an unpublished investigation with similar results. L&I has determined that it is possible to estimate hand force by comparison with such activities as holding a half ream of normal copy paper or opening a light duty automotive battery jumper cable and the final rule has been modified accordingly.

L&I based the choice of caution zone and hazard level for high hand force primarily on the studies of Roquelaure et al. (1997); Chiang (1993); English (1995); Armstrong (1987); Silverstein et al. (1986, 1987); Stetson (1993); Chaffin and Armstrong (1979); Moore and Garg (1994); and Kurppa et al. (1991). Roquelaure, for example, did a case control study of carpal tunnel syndrome, using clinical exam and positive nerve conduction tests. These investigators reported an odds ratio of 9 for pinching objects weighing more than 1 kg (2.2 pounds) but also an odds ratio of 8.8 for repetitive pinching with subcycles of less than 10 seconds. English also conducted a case control study among 580 orthopedic patients and 996 controls. He found an odds ratio for thumb disorders such as deQuervain's disease of 4.0 for repetitive pinching, of 3.2 for maintaining a fixed bent thumb and of 1.4 per 20 repetitions of wrist flexion and extension. With the exception of the Armstrong, Silverstein and Chiang studies, the ability to distinguish high force from high force combined with high repetitiveness is difficult. All of these studies took place in environments that tended to have cyclical, repetitive work. Stetson, for example, found median nerve abnormalities in symptomatic workers handling more than six pound loads per hand compared to those without heavy gripping, but virtually all the jobs studied were repetitive.

Using electromyography for quantification of forearm flexor muscle load, Silverstein et al. (1987) and Chiang et al. (1993) divided jobs into different hand force risk categories. In a cross-sectional study of manufacturing workers in seven different companies, Silverstein found an odds ratio for tendinitis of 6.1 for high force (more than 6 kg)-low repetition jobs compared to low force-low repetitive jobs, while controlling for age, sex, plant and life style factors in the analysis. For those exposed to both high force and high repetition, the odds increased to 15 for carpal tunnel syndrome, and 29 for hand wrist tendinitis. Chiang found an elevated odds of 1.8 for shoulder disorders and 1.6 for CTS for those fish processors exposed to 3 kg.

Considering the evidence as a whole, L&I concluded that there is an increased risk of hand and arm WMSDs with jobs requiring pinching objects greater than 2 pounds (equivalent to exerting an actual force of 4 pounds) or gripping objects greater than 10 pounds (equivalent to exerting an actual force of 10 pounds). The risk is increased further if pinching or gripping is combined with other risk factors such as repetitive motion or awkward postures. Therefore, for simplicity and ease of use the caution zone criteria are stated just in terms of hand force for a two hour duration while the hazard levels more fully take into account the higher level of risk for hand force together with repetitive movements or awkward postures. More specifically, Appendix B allows 4 hours of gripping or pinching if there are no other risk factors, but only 3 hours if there are highly repetitive motions or the wrists are in awkwardly flexed or extended postures.

Highly repetitive motion: Other than keying

Repetition refers to the frequency of movement and can be characterized in a number of different ways (e.g., cycle time, number of movements per minute, speed of movements, percent of the cycle performing the same exertion, percent of cycle in recovery). NIOSH found strong evidence for repetition, in combination with other risk factors, as a causal factor for neck, shoulder and hand/wrist WMSDs (Bernard 1997) NIOSH found causal evidence (but not "strong evidence") for repetition alone contributing to carpal tunnel syndrome and tendinitis.

In a case-control study Roquelaure et al. (1997, 1996) found increased risk of carpal tunnel syndrome and radial tunnel syndrome with cycle times of less than 30 seconds (OR=8.8 and 8.7 respectively).

In another case-control study English (1995) defined repetition as a posture occurring more than once per minute and reported an increase in risk of hand/forearm disorders with increasing frequency of wrist flexion/extensions.

In a cross-sectional study that measured repetition as less than 30 second cycle time or more than 50% of the cycle doing the same subcycle Silverstein (1987) found an increased risk of carpal tunnel syndrome (OR=5.5) compared to those in low repetition-low force jobs. Chiang (1993) found an increased odds ratio for shoulder disorders with the same definition of high repetition as Silverstein (OR=1.6) but not for carpal tunnel syndrome.

In a cross-sectional study of carpal tunnel syndrome and hand wrist tendinitis, Latko et al. (1999) studied repetitiveness among manufacturing workers based on the rapidity of movement and the possibility of pauses within the cycle. She then categorized the exposure into low, medium and high repetitive work. In the high repetitive category, the average number of repetitions per minute was 8 compared to 2.4 per minute in the low repetition group. Being in the high repetition group compared to the low repetition group increased risk (OR=3.1 for carpal tunnel syndrome and 3.2 for tendinitis) while controlling for a number of personal factors. There was little difference in force or postures between the jobs.

Leclerc (1998) reported an increased risk of CTS among industrial workers in a cross sectional study. The odds ratio was 1.3 for cycle times of 20-59 seconds and 1.9 for cycle times of less than 10 seconds.

In a cross-sectional study of 521 automobile assembly line workers and general population referents, Fransson-Hall et al. (1995, 1996) used a questionnaire to characterize work exposures, psychosocial and individual factors, and forearm-hand symptoms. Within the previous 6 months, 11% of male and 27% of female autoworkers had sick leave due to forearm-hand disorders. Repetitive motion was associated with forearm-hand disorders among both men and women. Significant risks were found with exposures greater than 45 minutes. The highest risks were found with exposures greater than four hours: For men the prevalence ratios were 4.7 for precision plus repetitive hand movements, 3.8 for precision plus repetitive finger movements, 7.6 for repetitive hand and finger movements, 1.2 to repetitive finger movements, 1.4 for repetitive hand movements, 1.7 for dorsal flexion, 1.3 for palmer flexion and 1.4 for ulnar deviation. For women the prevalence ratios for greater than four hours exposure were 10.0 for precision plus repetitive hand movements, 19.7 for precision plus repetitive finger movements, 3.6 for repetitive hand and finger movements.

Nordstrom (1997) reported the results of a population based case control study of carpal tunnel syndrome. Duration of wrist bending or twisting greater than 3 hours was associated with carpal tunnel syndrome (OR=2.6), while controlling for age and body mass index, but it was not clear whether this was static postural stress or repetitive stress.

The evidence is especially strong for the effects of combined exposure to repetition, force and awkward posture. Armstrong et al. (1987) and Silverstein et al. (1986, 1987) reported a multiplicative effect of high hand force and high repetition (OR = 15 to 29) compared to low force-low repetition jobs. The risk ranged from OR=3 to 6 when only one of the risk factors was present. Roquelaure (1997) reported high odds ratios for carpal tunnel syndrome based on high force (pinching >1 Kg) and high repetition (subcycle less than 10 seconds) and an increasing risk with an increase in the number of physical load factors. Punnett (1998) developed an index by combining risk factors (force, high repetition, posture and vibration). She reported an increase in prevalence of hand/wrist disorders and neck/shoulder disorders with an increase in the index. Within highly repetitive jobs (at least 27 movements per minute) handling lightweight parts, Schoenmarklin et al. (1994) found that jobs combining high repetition and awkward wrist postures were at particularly high risk, with an OR=5.0 for hand-wrist disorders on jobs with peak acceleration in the flexion/extension plane. Blanc et al. (1996) found that the risk of disability from carpal tunnel syndrome increased 1.7 times for every two hours of exposure to repetitive work with awkward wrist posture. Luopajarvi et al. (1979) reported an odds ratio of 7.1 for tenosynovitis among packers who used high hand force, deviated wrists and about 25,000 movements per day when compared to shop assistants. Kurppa et al. (1991) compared meatpackers in high force-high repetitive jobs with other workers and found increased risks for tenosynovitis (RR=29.5 for females and 11.1 for males) and for epicondylitis (RR=5.3 for females and 7.5 for males). Fransson Hall et al. (1995, 1996) as noted above reported higher odds ratios among men and women auto workers who used both high hand force and repetitive hand or finger movements for more than 4 hours compared to repetitive motions alone.

Moore and Garg (1994, 1995) used a job strain index that combined force, duration, repetitiveness and posture to assess the risk of distal upper extremity disorders in meat packing plant jobs. They also recorded presence or absence of contact stress, cold, and vibration. OSHA logs and employee medical records were reviewed. Job categories with reported disorders had significantly higher force and posture scores. Job categories with index scores above 5 had an increased risk of incidence of distal upper extremity disorders.

Based on the evidence as a whole and paying particular attention to studies by Fransson-Hall (1995, 1996) and Blanc (1996) L&I decided that work requiring the same motion every few seconds with little variation should be in the caution zone if done for more than 2 hours daily. For the hazard criteria, taking into account the studies by Armstrong (1987); Silverstein (1986, 1987); Punnett (1998); Kurppa (1991); Moore and Garg (1994, 1995) and others, L&I decided to allow different durations of exposure depending upon whether the work involved repetition alone or in combination with other risk factors. Setting unique hazard criteria for every specific combination of repetition, force, posture and body part would have been overly complex to the point of confusion and therefore administratively unworkable. Therefore, L&I established two specific criteria that are strongly supported by the scientific evidence: six hours of daily exposure to highly repetitive motions alone and two hours of daily exposure to highly repetitive motions in combination with high hand force and awkward wrist posture.

Highly repetitive motion: Keying

Bernard et al. (1994) reported an exposure-response relationship between hours of VDT use and hand/wrist disorders among newspaper workers. The OR was 1.3 for 4-6 hours, 2.1 for 6-8 hours and 3.3 for more than 8 hours, while controlling for personal and psychosocial factors at work. Polanyi et al. (1997) conducted a similar cross-sectional study of monthly upper limb pain among newspaper workers in Canada and found an OR of 1.5 for keying more than 5 hours compared to keying less than 1.5 hours. Faucett and Rempel (1994, 1996) examined MSD severity on questionnaire as well as psychosocial and individual factors. The odds of upper torso symptoms increased 1.4 for every hour of reported VDT use and the odds of upper extremity symptoms increased 1.49 for every hour of reported use, despite the fact that self-reports were found to overestimate the duration of exposure. Bergqvist (1992) found an odds ratio of 4.0 for hand-wrist WMSDs among new VDT users but not among others. Heyer et al. (1990) found an increased risk of hand/wrist symptoms among VDT users for more than 4 hours compared to less than 2 hours (PR=2.3) but did not find an increased risk for more than 6 hours compared to 4-6 hours of use. Nelson and Silverstein reported an increased odds of hand/arm symptoms with more than 6 hours of VDT use while controlling for demographic and psychosocial variables. Oxenburgh (1985) reported an odds ratio of 7.9 for hand wrist disorders for those using a VDT more than 4 hours per day compared to less than 3 hours per day. Studies that included a number of other factors along with VDT use tended to report more significant results. For example, Bergqvist et al. (1995) reported an odds ratio of 4.6 with VDT use more than twenty hours a week together with reported insufficiency of rest breaks and non-use of lower arm support when compared to non VDT work.

Hales et al. (1992, 1994) on the other hand found no association between duration of VDT use and upper extremity disorders among telecommunication workers. However, this study population did not do intensive keying (average less than eight words per minute). The author concluded that the results could not be generalized to more highly exposed groups.

Some studies have looked more specifically at intensive data entry, particularly in combination with awkward postures, and found an increased risk of hand/arm disorders with increasing duration of exposure (Bernard 1994; Heyer 1990; Polanyi 1997; Nelson 1998). DeKrom (1990) and English (1995) found no specific association with keying or finger tapping per se. Bergqvist (1995) reported an increased risk of hand/arm diagnoses when keying more than 20 hours per week was combined with an improper keyboard height and awkward wrist postures.

Some laboratory studies (Kier et al. 1998; Dennerlein et al. 1998) have observed increased carpal tunnel pressure with intensive keying activities, however, it is unclear whether keying itself is the critical factor or the constrained postures and static muscle contraction together with keying. Several studies have shown a higher risk for intensive data entry compared to VDT work that may allow for changes in postures and natural micropauses. Keir et al. (1998) have shown that wrist extension and flexion increase carpal tunnel pressures significantly, as does using extended fingers. Aaras et al. (1997) have shown that the trapezius muscles are more highly loaded when performing keying activities without adequate forearm support, particularly if the keyboard is too high, causing the shoulders to be shrugged.

The evidence indicates that if awkward postures were reduced, and there was sufficient recovery time from the static loading of upper extremity tissues, the risk associated with intensive data entry would be substantially reduced. In a small study of data entry operators, L&I found that intensive keying more than 5 hours per day was associated with increased upper limb disorders, but that when the intensive keying tasks were broken up with alternative tasks, the prevalence of upper limb and back disorders decreased substantially (SHARP 1993).

L&I noted the common finding that increased duration of intensive keying is associated with increased risk for neck-shoulder and upper extremity disorders. L&I then set the caution zone for intensive keying at 4 hours, a level at which there was strong and consistent evidence of risk. The evidence shows that the risk is less if there is time for rest breaks and there are no awkward postures. Therefore, intensive keying is allowed for up to 7 hours unless there are awkward postures in which case it is limited to 4 hours.

Repeated impact: Hands

Clinical case series have consistently reported an association between using the heel of the hand as a hammer and ulnar artery thrombosis (hypothenar hammer syndrome), however there have been few epidemiological studies of this syndrome (Vayssairat et al. 1987; DeMonaco et al. 1999; Ferris et al. 2000). One epidemiological study was done by Little and Ferguson (1972) comparing auto mechanics whose hands were used as a hammer more than once per day with a referent population of unexposed men. The prevalence of hypothenar hammer syndrome was 14% among the 79 hammerers compared to 0% among the referent population. Another epidemiologic study of hypothenar hammer syndrome identified vibration among miners and drillers, chain saw use among forestry workers and use of an impact wrench among concrete plant and iron foundry workers as possible causes (Kaji et al. 1993). Each of these occupations might also use hand hammering. All of these studies refer to repeated impacts, but none contains quantitative exposure response data. Based on the best available evidence, L&I made a prudent choice for the caution zone at more than 10 times per hour for more than two hours and set the hazard level at more than once per minute for two hours. L&I believes that compliance with these levels will reduce, but may not eliminate, hypothenar hammer syndrome.

Repeated impact: Knees

Thun (1987) found an odds ratio of 1.8 for prepatellar bursitis among carpet layers who kneeled but did not use a knee kicker compared with workers who did not kneel. There was a substantially higher risk (OR=3.2) for carpet layers who both kneeled and used a knee kicker. Village et al. (1993) conducted a biomechanical study of knee kicking versus using a power stretcher to stretch carpets and found tremendous impact force due to the kicker that was not ameliorated by using kneepads. Village also found that the productivity was greater with the power stretcher compared to the knee kicker. The average number or frequency of using a knee kicker was not described in the epidemiological study. Based on the best available evidence, L&I made a prudent choice for the caution zone at more than 10 times per hour for more than two hours and set the hazard level at more than once per minute for two hours. L&I believes that compliance with these levels will reduce, but may not eliminate, prepatellar bursitis.

Heavy, frequent or awkward lifting

The risks associated with heavy, frequent and/or awkward lifting have been well established. Smedley (1995); Venning (1987); Stobbe (1988); Arad & Ryan (1986) have all reported high risks of low back WMSDs (relative risks of 1.7 to 2.7) for jobs requiring lifting of more than one to five patients a day in health care settings. In a case referent study of hospitalization for herniated lumbar discs, Kelsey et al. (1984) found increased risks for lifting more than 25 pounds 25 times per day (RR=3.5); lifting more than 25 pounds while twisting more than 5 times per day (RR=3.1); and lifting more than 25 pounds per day while twisting and having the knee straight (RR=6.1). Macfarlane et al. (1997) and Kuh (1993) also reported increased risks of low back disorders (OR=1.3 to 2.8) for lifting or moving 25 or more pounds (Macfarlane) or 25 or more kilograms (Kuh). In a case control study of automobile assembly workers, Punnett (1991) found an increased risk of low back disorders with frequent lifts (more than 10 pounds more than once per minute). These studies provided the basis for establishing the caution zone criteria for heavy, infrequent lifting (more than 75 pounds once per day, more than 55 pounds more than 10 times per day); lighter, repetitive lifting (more than 10 pounds more than twice a minute for more than two hours per day); and awkward lifting (more than 25 pounds above the shoulders, below the knees or at arms length more than 25 times per day).

The Appendix B criteria for lifting take into account studies that examined combinations of risk factors. Liira (1996) found increased odds of long term or disabling low back WMSDs for bending/lifting more than 50 times per day (OR=1.7), for frequent lifts of less than 50 pounds (OR= 1.5), awkward trunk postures (OR=2.3) and whole body vibration (OR=1.8). As the number of risk factors increased, so did the risk.

Liles (1984, 1985) studied workers in jobs with repetitive manual handling tasks, using a Job Severity Index that included the weight of the load, individual lifting capacity, frequency of lift, and duration of task. Liles found an exposure-response relationship between the Index and the incidence rate of disabling low back WMSDs. Liles equated the Job Severity Index scores to the action limit (AL) and maximum permissible limit (MPL) from the 1981 NIOSH lifting equation. The disabling injury rate was 2.6 per 100 worker-years for those whose job was below the AL, 7.1 between the AL and MPL, and 11.6 for more than the MPL.

Marras (1995) used direct measurement (lumbar motion monitors) to identify high risk lifting tasks among those who do routine repetitive lifting. The principal elements in his model were load weight, frequency, distance of the load from the low back, twisting and the speed of movement. The high-risk jobs (OR=3.3) averaged 3.77 lifts per minute and 20 pound loads.

Snook (1978) used a psychophysical method to determine the maximum acceptable lifting weights and frequencies for men and for women and examined low back WMSDs among a group of insurance company policyholders. There was an increased risk of low back WMSDs if jobs required manual handling of loads above the maximum acceptable level for 75% of the population.

The full impact of forceful manual handling tasks on the back depends on several factors (Snook and Ciriello 1991; NIOSH 1994; Marras 1995; Brinckmann 1986): distance and location of the load from the spine; weight of the external load; frequency of lifting/lowering; velocity and rate of acceleration/deceleration; awkward postures such as twisting and bending to the side or front; quality of coupling or handholds.

NIOSH (Waters, 1993, 1994) has developed a Lifting Equation for employers to evaluate and improve their manual handling jobs. The 1991 NIOSH Lifting Equation takes into account most of these factors. The criteria for a Lifting Equation index of 1.0 was set so that "nearly all healthy workers could perform over a substantial period (e.g., up to 8 hours) without an increased risk of developing lifting-related LPB (low back pain)." Liberty Mutual researchers (Ciriello and Snook 1999) summarized manual handling activities of 2,442 industrial locations. The median lifting and lowering tasks were 1.9 and 1.8 using the NIOSH Lifting Equation, indicating a need for job redesign.

The NIOSH 1991 Lifting Equation has been used in several studies to assess risk of low back WMSDs. Waters, Baron et al. (1999) evaluated a large number of manual handling jobs and found that as the lifting index increased, so did the risk of low back disorders. There was a statistically significant high risk (OR=2.2) for work with a lifting index of 2 to 3. For a lifting index of 1 to 2 the risk was lower (OR=1.96) and not statistically significant. A low, non-significant odds ratio for a lifting index of more than 3 was based on a small number of employees and felt to be a result of a survivor effect. Wang (1998) has also found a linear relationship between an increased lifting severity index and increased low back disorders**.**

A number of people commented on the NIOSH lifting equation and questioned its validity for identifying hazards (e.g. United Parcel Service comments). L&I has considered these comments and concludes that use of the NIOSH lifting equation or a similar approach is a reasonable balance between simplicity and predictive value for identifying and controlling lifting hazards. Lavender has compared several manual handling assessment tools and commented that the L&I approach is reasonable (Lavender comments). Lavender, Oleske et al. (1999) compared 5 different manual handling assessment tools on assembly jobs characterized primarily as repetitive lifting of light to moderate loads: Ohio State Lumbar Motion Monitor (LMM) assessment, two versions of the UAW-GM risk factor checklist, the University of Michigan Static Strength Prediction Model (2DSSP) and the 1993 NIOSH Lifting Equation. OSHA 200 log reports of low back pain on each of 93 jobs was the outcome measure. There was modest correlation (>0.5) between the NIOSH Lifting Equation, the UAW-GM checklists and the LMM and relatively poor correlation with the 2DSSP model. The NIOSH model identified the most jobs as high risk whereas the 2DSSP model identified the most jobs as low risk. The 2SSSP is best suited for evaluating hazards for acute trauma because it does not take frequency or duration into account. The LMM takes individual factors into account the most. Marklin and Wilzbacher (1999) have also compared assessment tools, including the NIOSH lifting equation, 2DSSP, the LMM, and the Borg psychophysical assessment. They found that each of the methods had relative strengths and weaknesses. They found that the 2DSSP is best for estimating acute overload, the NIOSH lifting equation is best for relatively simple operations, and the LMM for more complex tasks.

L&I has concluded that the 1991 NIOSH lifting equation provides the most balanced and reasonable basis for evaluating lifting hazards, although its use in the field, where critics have pointed out that actual jobs may not match the NIOSH assumptions, tends to underestimate risk.

Other approaches, when used appropriately, are also useful and acceptable to L&I (e.g. biomechanical models and psychophysical models).

The NIOSH Lifting Equation is a practical tool and is in widespread use among safety professionals. For example, continuing education credits were given to occupational health nurses who learned how to use the equation (Garg 1995). L&I decided to base the hazard criteria for lifting on the NIOSH equation because of its practical applicability, widespread use and scientific soundness. However, the NIOSH Lifting Equation requires a degree of measurement and calculation that goes beyond the level of simplicity L&I intended for this rule. Therefore, L&I developed a simpler manual handling worksheet in Appendix B based on the NIOSH Lifting Equation. The proposed rule was designed so that using the Appendix B worksheet would define lifting hazards as jobs with Lifting Equation levels of approximately 2. However a number of comments from experts in manual handling research raised concerns that this level was inappropriately high because it would leave a high percentage of women at unacceptably high risk for overhead lifting (Lavender, Norman, Marras, Garg, Keyserling comments). The lifting index of 1.0 is estimated to protect 75 percent of healthy adult females and 99 percent of healthy males. A Lifting Index of 2.0 is expected to protect 20 percent of females and 80 percent of males, and a Lifting Index of 3.0 is expected to protect 1 percent of females and 27 percent of males. NIOSH recommends a Lifting Equation index of 1.0 for the design of jobs. L&I does not believe there is sufficient epidemiological evidence to set the index at 1.0 for employers, particularly considering the difficulty some employers would have in achieving this low level. The final rule has been modified to approximate Lifting Equation levels of approximately 1.5-1.7 at extended reach lifts and 2.0 at the least stressful near reach lifts. The department chose this as the best balance among safety, feasibility and simplicity.

Moderate to high hand-arm vibration

Vibrating tools have been known to cause vascular and neurological impairment in the hands since the 1920s. Bovenzi (1995) has reported a quantitative relationship between level of exposure (duration and intensity) and the development of hand-arm vibration syndrome (HAVS). He also found lower odds of HAVs among workers using vibration dampened chain saws compared to traditional chain saws. McGeoch and Gilmore (2000) recently reported a study of heavy engineering company workers who used chipping hammers, grinders and caulking hammers, whose acceleration levels were measured. They found a quantitative relationship between total hours of exposure and severity of neurological and vascular signs on physical exam, while controlling for age and smoking. Wasserman (1998) reports that after 8 years of 8-hour exposure to $2.8 m/s^2$, or 2-hours of $5.6 m/s^2$, or 30 minutes at $11.2 m/s^2$ at least 10 percent of the exposed population may be expected to have HAVS.

Some recent studies (Bovenzi 1991) have found associations between hand arm vibration and other upper extremity disorders, including carpal tunnel syndrome, epicondylitis and cervical disorders. Nordstrom et al. (1997) used a questionnaire to estimate exposure to power tool use among newly diagnosed carpal tunnel syndrome cases and population based controls. He found an increased odds of carpal tunnel syndrome with increased duration of exposure (OR=0.5 for less than one hour, up to OR=3.3 for more than 6 hours of self-reported exposure). This study did not evaluate exposure intensity.

A number of governments and private organizations have standards for both segmental and whole body vibration (Wasserman 1998). These standards include duration of use and vibration intensity of the tool. The vibration level is expressed as the amount of energy transmitted by the tool over a certain number of hours, using equivalent units of meters per second squared (m/s^2). For example, three hours of exposure to a tool with a vibration value of 4.1 m/s^2 is the equivalent of eight hours of exposure to 2.5 m/s^2. Thirty minutes exposure to a tool with a vibration value of 10m/s^2 would be equivalent to eight hours at 2.5 m/s^2. ANSI S3.34 (1986) uses weighted vibration measurements and a spectrum analysis. It provides limit values for acceptable daily exposure times for different vibration exposures. The European standard (Wasserman 1998) calculates the 8-hour energy-equivalent frequency-weighted acceleration sum based on the duration of use. It uses the following limit values: 1 m/s^2 is the threshold level for health risk alerts and preventive measures including worker education; 2.5 m/s^2 is the action level at which values should be put into the instructions and sales literature; 5 m/s^2 is the exposure limit level.

Pelmear and Leong (2000) reviewed the literature and concluded that these existing occupational standards and guidelines for segmental vibration provide inadequate protection for impact vibration. They recommend a more stringent level to keep the prevalence of Raynaud's phenomenon below background rate of less than 5%: 1.8m/s^2 for 8 hours or less, 2.58 m/s^2 for 4 hours or less, 3.6 8m/s^2 for 2 hours and less, and 5.0 8m/s^2 for 1 hour or less. They also recommend extra precautions for impact vibration and high frequency vibration exposure although specific levels are not currently recommended. Bovenzi (comments) also advised more stringent criteria for exposure than currently in the ISO HAV standard. He cautioned that the L&I proposal does not have a vibration ceiling for short but intense exposures.

While L&I believes that the current voluntary standards on hand arm vibration exposure will eventually be reduced, particularly to address neurological effects, the existing standards were used to provide a benchmark for the caution zone and Appendix B criteria. However, while vibration exposure is best measured with triaxial accelerometers, which take into account the manufacturer's declared vibration value, how well the tool has been maintained and the surface on which the tool is being used, L&I recognized that these devices are not readily available to most employers. Therefore L&I used the formulas in the voluntary standards to estimate duration of exposure based on the manufacturer's declared vibration value. L&I then set the caution zone levels to be roughly equivalent to 2.5 m/s^2 and the appendix B levels to be equivalent to 5 m/s^2, based on an 8-hour energy equivalent. It is likely that this method will underestimate true exposures. While it would be scientifically preferable that actual measurements be taken, the surrogate values in the rule will allow employers to make a reasonable determination of whether they have hazardous exposures without the need for expensive instrumentation.

Table 7
Specific evidence for caution zone job criteria - Examples

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
AWKWARD POSTURES					
Hands above head > 2 hours / day	• Auto assembly • Case-referent	Video observation, more than 90^o shoulder abduction/flexion	Shoulder disorders at medical dept and by physical exam	RR=2.3-3.2 for >1/minute 2.0-2.5 for <10% of cycle 3.9-6.1 for >10% of cycle	Punnett 2000
	• Meat packing and chemical workers • Cross-sectional	Questionnaire/video Arms raised > 30^o or >10/minute	Impingement syndrome (3 months pain and physical exam)	OR = 5.3 for current workers 7.9 for former workers Increase with cumulative exposure	Frost 1999, 1998
	• Construction workers • Cross-sectional	Questionnaire Work with hands above shoulder	Questionnaire (some physical exams) Severe neck / shoulder pain with functional disability	OR = 1.1 for <1 hour 1.5 for 1-4 hours 2.0 for >4 hours	Holmstrom 1992
	• Orthopedic patients • Case-referent	Interview Shoulder postures	Wrist and forearm disorders by clinical examination	OR= 1.62 per hour of uninterrupted shoulder rotation with arm elevated for hand wrist disorders	English 1995
Work with Neck bent >30^o without support or ability to vary	• Electronics assembly • Cross-sectional	Video analysis Neck and upper arm postures	Neck, shoulder and arm symptoms by interview and physical examination	Increasing duration of cycle in neck flexion >20^o associated with increasing severity of neck symptoms in regression analyses	Kilbom 1986
Work with back bent >30^o without support	• Auto assembly • Case-referent	Video observation Mild flexion>20^o Severe flexion>45^o	Low back pain requiring medical visit	OR=4.2 for >20^o <10%cycle 6.1 for >20^o, > 10% cycle	Punnett 1991
	• Auto workers • Case-referent	Video analysis Quasi-dynamic biomechanical model Psychosocial	Low back pain cases reported at company clinics	OR=1.4 for >20^o flexion >20% shift (1 hr) 2.4 for >50^o peak flexion, 1.7 for higher peak lumbar	Kerr 2000

Table 7 Specific evidence for caution zone job criteria - Examples

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
		questionnaire		shear 2.0 for higher disc compression 1.9 for higher peak hand force 2.6 for poor work environment 2.2 for higher education, 1.7 for high job satisfaction 1.6 for high coworker support 2.0 for BMI 2.2 for prior WC claim	
	• General population Longitudinal	Interview, questionnaire Psychosocial, individual factors Leisure activities considered	Seek health care for new low back pain (exclude chronic back pain cases)	Females RR=2.8 for vehicle driving >4 hours, 2.0 for high physical load (METs>3) Males RR=1.8 for forward bending > 60 minutes, RR=1.6 bending >1minute<59 minutes/day, 1.4 for heavy lifting, 2.1 for poor job satisfaction, 1.8 for routine work, don't learn new things	Vingard et al. 2000
Squatting or kneeling > 2 hours/day	• Carpet layers, tile and terrazzo setters, millwrights, bricklayers • Cross-sectional	Questionnaire, interview Kneel and use knee as hammer versus kneel only versus neither kneel or use knee as hammer	Physical exam and x-ray Prepatellar Bursitis Knee aspirations	OR=1.8 for prepatellar bursitis, kneeling 4.9 for knee aspirations, kneeling 142 for knee aspirations, high kneeling at age 25	Thun et al. 1987
HIGH HAND FORCE					
Holding 2 pound object with pinch or pinch force > 4 pounds >2 hours	• Industrial workers • Case-control	Observation Interview	Carpal tunnel syndrome on exam and nerve conduction	RR=8.8 for subcycle < 10 sec 9.0 for >1 kg 6.0 for no breaks 15% of work time 6.3 for no rotation 5.0 for manual workstation	Roquelaure 1997

Table 7 Specific evidence for caution zone job criteria - Examples

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
				supply 3.2 for parity 3+ Increased risk with increased number of factors	
	• Fish processing • Cross-sectional	EMG forearm flexor Arm movements, repetition and force (Repetitive defined as <30 sec cycle time or 50% same fundamental cycle)	Shoulder Epicondylitis, Carpal tunnel syndrome by physical examination	Force OR=1.8 for shoulder 1.6 for CTS Repetition OR=1.6 for shoulder 1.1 for CTS (NS) 2.0 for use of oral contraceptives	Chiang 1993
	• Orthopedic patients Case-referent	Interview Pinching	Clinical examination , thumb disorders including deQuervain's tenosynovitis	OR=4.0 for pinching	English 1995
	• Auto upholstery sewing • Case Control	Video analysis Electromyography Duration and force of pinch posture	Carpal tunnel syndrome based on medical records	Cases used pinch positions more often (52 vs. 44% of time) and with greater force (4.5 kp vs. 3.8 kp) than referents	Armstrong and Chaffin 1979
Power grip 10# load or exert > 10# grip force > 2hrs.	• Automobile manufacturing workers • Cross-sectional	Observational checklist Note: 59% handling 6 lbs. per hand were also carrying >10 lbs. total.	Questionnaire, physical exam, electrodiagnostic tests	Abnormal electrodiagnostic tests for >1/3 shift handling >5 pounds per hand Significant difference between the symptomatic and asymptomatic employees.	Stetson 1991 Stetson 1993
	• Industrial workers • Cross-sectional	Video analysis, electromyography, estimates of force Considered hobbies, demographics, life style	Interview and physical examination Hand/wrist tendinitis	OR=6.1 for high force-low repetition	Silverstein 1986 Armstrong 1987
Highly Repetitive Motion					
Same motion every few seconds for	• Auto workers and general population	Questionnaire and observation	Questionnaire and physical	OR=1.8 for finger movements >45/minute for women	Fransson-Hall 1995, 1996

Table 7 Specific evidence for caution zone job criteria - Examples

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
neck, shoulder, elbow, wrists or hands > 2 hours/day	controls • Cross-sectional	Repetition of hand and finger movements	examination Forearm and hand WMSDs	1.4 for finger movements >45/minute for men 2.4 for hand movements >45/minute for women 1.7 for hand movements >45/minute for men	Bystrom et al. 1995
Intensive keying > 4 hours per day	• Newspaper workers • Cross-sectional	Observation and questionnaire Considered psychosocial factors, demographics, hours of computer use	Hand/wrist disorders Symptoms severity	Hours of computer use OR=1.0 for 2<4 hours 1.3 for 4<6 hours 2.1 for 6<8 hours 3.3 for $\geq$ 8 hours	Bernard 1994
	• Newspaper workers • Cross-sectional	Questionnaire	Monthly upper limb pain on questionnaire	OR=1.5 for keying>5 hours versus 1.5 hours	Polanyi 1997
Intensive keying > 4 hours per day	• VDT operators • Cross-sectional	Observation analysis Self reported VDT use Considered psychosocial and individual factors	Questionnaire, MSD severity	OR=1.43 per hour of VDT use for upper torso 1.49 per hour of VDT use for upper extremity	Faucett and Rempel 1994, 1996
Repeated Impacts					
Hand as a hammer	• Auto maintenance shop workers • Cross-sectional	Interview Use hand as hammer more than once per day Considered life style and individual factors	Physical exam including doppler test Hypothenar hammer syndrome (thrombosis of ulnar artery)	Hypothenar hammer syndrome 14% among 79 hammerers 0.0% among 48 non hammerers	Little and Ferguson 1972
Knee as a hammer	• Carpet layers; tile and terrazzo setters, millwrights, bricklayers • Cross-sectional	Questionnaire Kneel and use knee as hammer versus kneel only versus neither kneel or use knee as hammer	Questionnaire, interview Physical exam and x-ray	Prepatellar Bursitis OR=3.2 for bursitis for knee kicker and kneeling 1.8 for kneeling 5.3 for frequent users of knee kicker	Thun et al. 1987
Heavy, Frequent, or Awkward Lifting					
Lift > 75 pounds 1/day	• Registered Nurses • Cross-sectional	Questionnaire Considered non-work activities	Questionnaire Low back pain lasting 48 hours in last 12 months	OR=1.4 for lift > 10 patients/week 4.4 for low back pain prior to study year 1.8 for other spinal pain	Mandel and Lohman 1987

Table 7 Specific evidence for caution zone job criteria - Examples

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
				1.5 for aerobics 3x/week	
	• Nurses • Cross-sectional	Lifts per shift on questionnaire	LBP in previous 12 months	OR=2.5: >6 lifts per shift	Arad and Ryan 1986
	• Nurses • Longitudinal	Detailed interviews with supervision	Back pain on OSHA 200 log	OR= 2.2 for lift >5 patients versus <2 patients per shift. Survival analysis shows significant difference over time between "lifters" and infrequent lifters.	Stobbe et al. 1988
	• Nurses • Longitudinal	Questionnaire at baseline and post injury. Daily lifter: >22 lbs. >1/day Occasional:<1/day Light: <10 lbs.	Back pain reported to employee health office	OR=2.2 for lift >1 patient versus 0 patients	Venning et al. 1987
Lift > 55 # > 10/day	Nurses Cross-sectional	Questionnaire Frequency of patient handling tasks per shift	Questionnaire Low back pain	OR=1.4 for lifting > 1 patient per day 2.1 for frequent mental stress	Smedley et al. 1995
	• General population • Retrospective for back pain • Prospective for exposure data	Regular lifting of loads >25 Kg (>55 lbs.)	Interview Sciatica, lumbago, severe low back pain ever before age 43	RR=1.3 for regular lifting of >25 kg	Kuh et al. 1993
Lift >10 # >2/minute >2 hours	• Auto assembly • Case-referent	Video analysis	Physical exam Low back pain requiring medical visit	OR=2.2 for lifting > 10 lbs	Punnett 1991
	• Multiple industries, 403 jobs • Cross-sectional	Lumbar motion monitor Video analysis	OSHA 200 logs Turnover	OR = 3.3 for maximum moment and high vs. low risk jobs (high risk jobs average 3.7 lifts/min and 20 lbs.)	Marras et al. 1993,1995
Lift >25# above shoulder, below knee, extended reach > 25/day	• Hospital patients with multiple occupations • Case-referent	Self-reports Lifting 25 lbs. below knee, above shoulder, or arms' length at least 25 times per workday Lifting while twisting	Hospitalized for herniated lumbar disc	RR=3.5 for lifting > 25 lbs., >25 lifts/day 3.1 for >25 lbs. and twisting, >5 lifts/day: 6.1 for lifting > 25 lbs. and twisting w/knee straight:	Kelsey 1984
	• Working population	Questionnaire of	Long term or	ORs for blue collar:	Liira et al.

Table 7 Specific evidence for caution zone job criteria - Examples

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
	Ontario • Cross sectional survey	physical exposures, demographics, smoking, occupation	disabling back pain	1.7 for bend/lift > 50 times/day 1.5 for frequent lifts (<50 lbs) 1.8 for whole body vibration 2.3 for awkward back posture 1.4 for any of the above 2.5 for 2 of the above 3.3 for 3 of the above	1996
	• Construction workers Prospective	Validated self-reports Psychosocial questionnaire	Questionnaire Low back pain	PR=2.6 for laying stones>10kg (22lbs) > 2 hrs/day 1.8 for >0<2 hrs/day 1.8 for intermediate stone load 4.0 for high stone load	Latza 2000
Moderate to High Hand-Arm Vibration					
High vibration > 30 minutes/day	• Heavy engineering company workers (165) exposed to vibration • Cross-sectional	Questionnaire Chipping, caulking hammers, pneumatic grinders. Acceleration levels of tools measured. Considered demographics, smoking status	Physical examination, staging of neurological and vascular components of HAVS	Relationship between hours of exposure and severity of neurological and vascular signs, controlling for age, smoking.. Chipping hammers have higher acceleration, cause more damage than grinders for same exposure. Exposure times: welders 1.5 hours, fitters 2 hours, dressers 5 hours	McGeoch and Gilmour 2000
Moderate vibration > 2 hours/day	• Chain saw operators (65) and controls (31) • Cross-sectional	Observational analysis Vibration measurements No differences between groups on other exposure factors than vibration	Interview and clinical examination Systemic diseases, demographic, body mass index	ORs for vibration dose <7.5m/s^2 vs. >7.5 m/s^2 OR for tension neck syndrome = 0.9 vs. 3.8 OR for cervical=2.8 vs. 10.7 OR for epicondylitis=3.0 vs. 8.5 OR for CTS=13.6 vs. 39.8	Bovenzi et al. 1991
	• Forestry workers (222) and controls (195) • Cross-sectional	Workplace assessment questionnaire Considered demographics, smoking, alcohol use	Questionnaire Finger blanching Cold provocation	Lifetime exposure ln (m^2s hd) OR=4.1 for <19 4.7 for 19-20 9.4 for 20-21 34.3 for >21.	Bovenzi et al. 1995

TABLE 8
SPECIFIC EVIDENCE FOR APPENDIX B CRITERIA - EXAMPLES

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
AWKWARD POSTURES					
Hands above head > 4 hours / day	• Auto assembly • Case-referent	Video observation, more than 90^o shoulder abduction/flexion	Shoulder disorders at medical dept and on physical exam	RR=2.3-3.2 for >1/minute 2.0-2.5 for <10% of cycle 3.9-6.1 for >10% of cycle	Punnett 2000
	• Meat packing and chemical workers • Cross-sectional	Questionnaire/video Arms raised > 30^o or >10/minute	Impingement syndrome (3 months pain and physical exam)	OR = 5.3 for current workers 7.9 for former workers Increase with cumulative exposure	Frost 1999, 1998
	• Construction workers • Cross-sectional	Questionnaire Work with hands above shoulder	Questionnaire (some physical exams) Severe neck/ shoulder pain with functional disability	OR = 1.1 for <1 hour 1.5 for 1-4 hours 2.0 for >4 hours	Holmstrom 1992
	• Female industrial workers in repetitive jobs • Cross-sectional	Video observation Shoulder elevation and abduction Considered psychosocial factors	Physical exam, neck/shoulder WMSDs	Median frequency or duration of upper arm movements or posture for subjects with and without WMSDs Percent of time >30^o: 14% vs. 7% Percent of time >60^o: 1% vs. 0%	Ohlsson 1995
	• Forest industry workers • Longitudinal	Validated questionnaires Considered psychosocial, individual factors	Questionnaire Radiating neck pain lasting more than 8 days	OR=1.2 for hands above shoulder >0.5-1 hour 1.6 for >1 hour 1.9 for obesity 1.7 for much mental stress	Viikari-Juntura et al. 2000
Work with Neck bent >45^o without support or ability to vary > 4 hours/ day	• Female industrial workers in repetitive work • Cross-sectional	Video observation of industrial workers Neck flexion > $30^{o,}$ Considered psychosocial factors	Physical exam Questionnaire, Neck/shoulder WMSDs	Median frequency or duration of upper arm movements or posture for subjects with and without WMSDs % time >15^o flexion, p=0.03	Ohlsson 1995

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
				multivariate analysis: neck flexion movements p=0.005	
	• Electronics workers • Cross-sectional	Video analysis Neck and upper arm postures	Interview, clinical examination Neck and upper arm symptoms	Regression analysis: Increasing duration of cycle in neck flexion >20^o associated with severity of neck symptoms	Kilbom 1986
Work with back bent >30^o without support > 4 hours/day	• Auto assembly • Case-referent	Video observation Mild flexion>20^o Severe flexion>45^o	Low back pain requiring medical visit	4.4 for >20^o <10%cycle 8.9>45^o, > 10% cycle	Punnett 1991
Work with back bent >45^o without support > 2 hours/day	• Auto assembly • Case-referent	Video observation Mild flexion>20^o Severe flexion>45^o	LBP requiring medical visit	RR=4.4 for >20^o <10% cycle 8.9 for >45^o >10% cycle	Punnett 1991
	• Auto workers • Case-referent	Video analysis Quasi-dynamic biomechanical model Psychosocial questionnaire	Low back pain cases reported at company clinics	OR=1.4 for >20^o flexion >20% shift (1 hr) 2.4 for >50^o peak flexion, 1.7 for higher peak lumbar shear 2.0 for higher disc compression 1.9 for higher peak hand force 2.6 for poor work environment 2.2 for higher education, 1.7 for high job satisfaction 1.6 for high coworker support 2.0 for BMI 2.2 for prior WC claim	Kerr 2000
	• Construction workers • Cross-sectional	Questionnaire Stooping	Questionnaire Severe back pain	RR=1.3 for stooping < 1 hour/day 1.9 for 1-4 hours/day 2.6 for > 4 hours/day	Holmstrom 1992
	• Crane operators, concrete workers • Cross-sectional	Observation Bending and twisting	Questionnaire Back pain in past 12 months	OR=2.8 for bending/twisting	Burdorf 1991
Squatting > 4 hours/day	• General practice population • Case referent	Interview Kneeling on job held longest before onset of symptoms	X-ray Knee osteoarthritis	OR=6.9 for squatting > 30 minutes versus <30 minutes/day	Cooper et al. 1994

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
	• Carpet layers and carpenters vs. compositors • Cross-sectional	Observation Percent of working time kneeling or squatting	X-ray, questionnaire Osteoarthritis of the knee Knee pain more than 320 days	Carpet layers OR=5.3 for >4 hours kneeling/squatting (symptoms) 2.3 for >4 hours kneeling/squatting (osteoarthritis) Carpenters OR=2.5 for >4 hours kneeling/squatting (symptoms) 1.3 for >4 hours kneeling/squatting (osteoarthritis)	Jensen et al. 1997 Jensen et al. 2000
Kneeling > 4 hours/day	• Carpet and floor layers versus painters • Cross-sectional	Observation Percent of time kneeling or squatting [note: Finnish carpet layers don't use knee kickers]	Physical exam, x-rays Knee WMSDs	RR= 9.5 for bursitis, 42% of time kneeling, 3% of time squatting	Kivimäki et al. 1992
	• General practice population • Case-referent	Interview Kneeling in job held longest before onset of symptoms	X-ray Knee osteoarthritis	OR= 3.4 for kneeling >30 min/day vs. < 30 min/day	Cooper et al. 1994
	• Carpet layers and carpenters vs. compositors • Cross-sectional	Observation Percent of working time kneeling or squatting	X-ray, questionnaire Osteoarthrosis of the knee Knee pain more than 30 days	Carpet layers OR=5.3 for >4 hours kneeling/squatting (symptoms) 2.3 for >4 hours kneeling/squatting (osteoarthritis) Carpenters OR=2.5 for >4 hours kneeling/squatting (symptoms) 1.3 for >4 hours kneeling/squatting (osteoarthritis)	Jensen et al. 1997 Jensen et al. 2000 (in press)

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
High Hand Force					
High hand force > 4 hours/day	• Industrial workers • Cross-sectional	Video and emg analysis Grip force and repetition Considered hobbies, demographics	Interview and physical examination, Hand/wrist tendinitis	OR=6.1 for high force-low repetition	Armstrong 1987
	• Industrial workers • Cross-sectional	Video and EMG analysis Grip force and repetition (6 kg as cutoff for force; reference value for repetition was cycle time <30s or 50% of the cycle time involved performing the same type of fundamental cycles)	Questionnaire and physical exam Hand/wrist disorders	OR=5.2 for high force (compared to low force/low repetitive)	Silverstein 1986,1987
	• Industrial workers • Case-control	Observation Video analysis Weight of loads handled	CTS on exam, electrodiagnostic	OR=9.0 for >1 Kg	Roquelaure 1997
	• Automobile manufacturing workers • Cross-sectional	Observational checklist (Note 59% handling 6 lbs. per hand were also carrying >10 lbs. total).	Questionnaire, physical exam, electrodiagnostic tests	Abnormal electrodiagnostic tests for >1/3 shift handling >5 pounds per hand Significant difference between the symptomatic and asymptomatic employees.	Stetson 1991 Stetson 1993
Forceful pinching (>2 lbs.) with high repetition > 3 hours/day	• Auto assembly workers and general population • Cross-sectional	Questionnaire Physical work load Considered psychosocial factors	Questionnaire Distal extremity symptoms in last 7 days Sick leave due to symptoms	**Males** OR=4.7:for precision + repetitive hand moves > 4 hours 3.8 for precision and repetitive finger moves > 4 hours 7.6 for precision finger and hand movements **Females**	Fransson-Hall 1995

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
				OR=10.0 for precision + repetitive hand moves > 4 hours 19.7 for precision and repetitive finger moves > 4 hours 3.6 for precision finger and hand movements	
Forceful pinch (>2 lbs.) and wrist flexion>45^{o} or extension >30^{o} > 3 hours	• Fish processing • Cross-sectional	Observation Repetition and force	Physician diagnosed shoulder, elbow and wrist WMSDs	Shoulder WMSDs OR=1.6 for repetitive movement 1.8 for sustained forceful movement Carpal Tunnel Syndrome OR=1.8 for sustained forceful movement	Chiang et al. 1993
	• Meatpacking workers • Prospective	Observation Force, repetition	Physical examination Tenosynovitis, peritendinitis, epicondylitis	Tenosynovitis IR=<1% in nonexposed 5.3% in female packers 16.8% in female sausage makers 12.5% in male meatcutters Epicondylitis IR=1% in unexposed 11.3% in female sausage makers 7.0% in female packers 6.4% in male meat cutters	Kurppa 1991
Forceful gripping (> 10 lbs.) with high repetition > 3 hours/day	• Industrial workers in 6 industries • Cross-sectional	Video and EMG analysis Grip force and repetition (6 kg as cutoff for force; reference value for repetition was cycle time <30s or 50% of the cycle time involved performing the same type of fundamental cycles)	Physical exam, questionnaire Hand/wrist WMSDs	Hand/wrist WMSDs OR=29.1 for high force and high repetition Carpal tunnel syndrome OR=15 for high force and high repetition	Silverstein 1986, 1987

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
	• Fish processing • Cross-sectional	Observation Repetition and force	Physician diagnosed shoulder, elbow and wrist WMSDs	Shoulder WMSDs OR=1.6 for repetitive movement 1.8 for sustained forceful movement Carpal Tunnel Syndrome OR=1.8 for sustained forceful movement	Chiang et al. 1993
Forceful grip (>10 lbs) and wrist flexion>45^o or extension >30^o > 3 hours	• Carpal tunnel syndrome patients and general population • Case control	Questionnaire Wrist flexion/extension Considered individual factors	Physical examination and neuro-physiological tests	Flexed wrist: RR=1.5 for 1-7 hrs/week 3.0 for 8-20 hrs/week 8.7 for >20 hrs/week Extended wrist RR=1.4 for 1-7 hrs/week 2.3 for 8-20 hrs/week 5.4 for >20 hrs/week (Keying and pinching not significant)	DeKrom 1990
Highly Repetitive Motions					
Same motion every few seconds > 6 hours	• Industrial workers in six industries • Cross-sectional	Video and EMG analysis Grip force and repetition (6 kg as cutoff for force; reference value for repetition was cycle time <30s or 50% of the cycle time involved performing the same type of fundamental cycles) Considered demographics, lifestyle, systemic diseases	Physical exam and questionnaire Carpal tunnel syndrome	OR=5.5 for high repetitive versus low repetitive	Silverstein 1987
	• Industrial workers • Cross-sectional	Video observation Repetition on a 0-10	Interview, physical exam,	Tendinitis OR=3.2 for highest (mean rating 8)	Latko 1999

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
		scale (8 denoted rapid steady motion/exertion; no regular pauses, corresponding well to the definition of "highly repetitive motion" in the rule. These jobs were performed all day)	electrodiagnostic studies Carpal tunnel syndrome, tendinitis	vs lowest third of jobs Carpal tunnel syndrome OR=3.1 for highest (mean rating 8) vs lowest third of jobs	
	• Industrial workers • Cross-sectional	Questionnaire, observation Note: high exposures to repeated high force in control group underestimates magnitude of effect.	Clinical exam Carpal tunnel syndrome	RR=1.3 for cycle time 20-59 seconds 1.9 for cycle time <10 seconds 2.2 for "just in time production"	Leclerc et al. 1998
	• Industrial workers • Case-control	Observation Interview Cycle time, number of motions per cycle	Physical exam, nerve conduction testing Carpal tunnel syndrome	RR=8.8 for subcycle < 10 sec 9.0 for >1 kg 6.0 for no breaks 15% of work time 6.3 for no rotation 5.0 for manual workstation supply 3.2 for parity 3+ Increased risk with increased number of factors	Roquelaure 1997
	• Factory workers, women • Prospective	Electromyography Light repetitive work	Clinical examination Trapezius myalgia	Incidence=10-20% at 10 weeks after hire 20-30% at 20 weeks 40-50% at 30 weeks 55-60% at 50 weeks	Veiersted et al. 1993
Repetitive wrist flexion>45^o or extension/ulnar deviation >30^o > 3 hours	• Population based • Case control	Questionnaire, validated with observation analysis Bending/twisting of wrists	Newly diagnosed carpal tunnel syndrome cases	OR=2.4 for <2 hours (NS) 1.3 for 2-3 hours (NS) 2.6 for >3-6 hours 2.1 for >7 hours BMI was a significant predictor	Nordstrom 1997

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
	• US population • Cross-sectional	• Interview • Repetitive wrist bending	Interview Disability due to carpal tunnel syndrome	OR=1.7 per 2 hours of repetitive wrist bending	Blanc 1996
Repetitive wrist flexion>45° or extension/ulnar deviation >30° > AND forceful exertions > 2 hours	• Supermarket cashiers • Cross-sectional	Observation/video analysis Repetition: Hand: 27-30 per minute Force: Low/moderate	Questionnaire and physical exam Shoulder or hand wrist WMSDs	OR=8.4 for checker-scanners 3.5 for >25 checker hours per week	Baron et al. 1992
	• Meatpackers and sausage makers • Prospective	Job Title Strenuous vs. non-strenuous	Examination Reports to medical department Tenosynovitis and epicondylitis	Tenosynovitis RR=29.5 for females 11.1 for males Epicondylitis RR=5.3 for males 7.5 for females	Kurppa et al. 1991
	• Stamping and engine plant workers • Cross-sectional	Psychophysical scores combining force, repetition and awkward postures Considered individual factors (psychophysical estimates were similar to observed exposures)	Physical examination and interview Shoulder and hand/wrist WMSDs	Exposure-response relationships OR=2.6-3.3 for shoulder 2.1-2.6 for hand/wrist	Punnett 1998
	• Packers and shop assistants • Cross-sectional	Observational analysis Static muscle load, hand force, wrist posture, repetition	Interviews Physical exams Tenosynovitis	OR=7.1 for packers compared to shop assistants Packers: static muscle load, high hand force, deviated wrists 25,000 movements/day	Luopajarvi et al. 1979
	• Auto assembly workers • Cross-sectional	Questionnaire (later evaluated by physical exam) Wrist posture, repetition	Symptoms in last 7 days, later evaluated on physical exam	OR=1.5-1.8 for wrist postures and movements>4 hours versus <2 hours 3.8-7.6 for pinching and repetition, men	Fransson-Hall 1995, 1996 Bystrom 1995 Hägg

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
				3.6-19.7 for pinching and repetition, women	1997
	• Industrial workers • Cross-sectional	Electrogoniometers Video analysis Flexion/extension	OSHA 200 log Cumulative trauma disorders	OR=5.0 for Peak Flexion/extension acceleration between 5220-6541 $^{o}/s^{2}$ >	Schoenmarklin et al. 1994
Intensive keying > 7 hours/day	• Clerical workers • Cross-sectional	Questionnaire VDT use	Neck Pain	OR=1.8 for 0.5-3 hours 4.0 for 4-6 hours 4.6 for ≥ 7 hours	Rossignol 1987
	• Newspaper workers • Cross-sectional	Observation and questionnaire Hours of computer use Considered demographic and psychosocial factors	Questionnaire Hand/wrist symptoms severity	OR=1.0 for 2<4 hours 1.3 for 4<6 hours 2.1 for 6<8 hours 3.3 for ≥ 8 hours	Bernard 1994
	• Office workers • Prospective	Questionnaire VDT use (not just intensive keying)	Questionnaire Hand/arm pain >1-3 days/week in previous 4 weeks	OR=1.8 for >6 hours/day 0.4 comfortable desk 0.5 for physical satisfaction with work station 1.8 for number of times outside/day.	Nelson et al. 1998
Keying > 4 hours with awkward postures	• Office workers (322) • Cross-sectional	Psychosocial questionnaire Hours per week keying	Questionnaire, clinical examination Hand/arm and neck WMSDs	OR=4.6 for hand/arm diagnoses with >4 hrs of VDT work and limited rest breaks and non use of arm support 2.2 for cervical diagnoses for >20 hrs per week of VDT work and spectral glare	Bergqvist et al. 1995
	• VDT workers (260) • Cross-sectional	Questionnaire, observation Considered psychosocial factors	Questionnaire, clinical examination Tension neck syndrome and hand/arm disorders	Tension neck syndrome OR =7.4 for limited breaks 4.4 for too high keyboard Hand/arm diagnoses OR=2.7 for limited rest breaks 2.7 for no lower arm support.	Bergqvist et al. 1995
Repeated Impacts					
Hand hammering > 1/minute > 2	• Auto maintenance shop workers	Interview Use hand as hammer	Physical exam including doppler	Hypothenar hammer syndrome 14% among 79 hammerers	Little and Ferguson 1972

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
hours/day	• Cross-sectional	more than once per day Considered life style and individual factors	test Hypothenar hammer syndrome (thrombosis of ulnar artery)	0.0% among 48 non hammerers	
Using knee as hammer >1/minute >2hours/day	• Carpet layers; tile and terrazzo setters, millwrights, bricklayers • Cross-sectional	Kneel and use knee as hammer versus kneel only versus neither kneel or use knee as hammer	Questionnaire, interview Physical exam and x-ray	Prepatellar Bursitis OR=3.2 for bursitis for knee kicker and kneeling 1.8 for kneeling 5.3 for frequent users of knee kicker	Thun et al. 1987
Heavy, Frequent or Awkward Lifting					
Manual handling combination of load, lift frequency, posture, twisting	• 50 jobs from 4 industrial sites • Cross-sectional	NIOSH 1991 Lifting Equation Exposed to at least 25 lifts/day. Mean weights handled: 24.5, 38.4 and 46.3 # in the three LI categories, included healthy worker effect at LI>3 (Note: method overestimates exposure and underestimates risk) Considered psychosocial factors and demographics	Back pain > 1 week in last 12 months	Prevalence 4% with Lifting Index = 0 22% with LI=0-1 25% with LI=1-2 34% with LI=2-3 26% with LI>3 Risk OR=1 with LI=0 1 with LI=0-1 (NS) 2 with LI=1-2 (NS) 2.25 with LI=2-3 1.1 with LI>3 (NS)	Waters 1999
	• 101 different manual handling jobs • Prospective	Detailed job analysis. Job severity index (JSI - includes duration, frequency, weight, capacity) Considered demographics	Company medical records, insurance data, anthropometry at baseline Disabling injury rate (DIR)	DIR<2 for JSI<1.5 >4.5 for JSI=2 >5.8 for JSI=3 >6.6 for JSI=4 Using approximation of 1981 NIOSH equation: DIR=2.6 for ~<AL	Liles 1984, 1985

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
				DIR=7.1 for ~ AL.<MPL DIR=11.6 for ~ >MPL	
	• Various industries • Questionnaire survey (Liberty Mutual Loss Prevention Specialist survey covering 6,000 locations)	Weight, force, sizes of manual handling tasks, selection and training policies Psychophysical studies	Most recent back injury per policy holder	OR> 2.0 for jobs where <75% acceptable based on psychophysical studies. Selection techniques, training in safe lifting techniques were ineffective 70% of injuries were associated with lift/push/pull/carry tasks	Snook et al. 1978
	• Manual handling workers in 15 workplaces • Cross-sectional	Observation and measurements NIOSH Lifting Index (LI) (1991)	Interview Sought treatment for severe low back symptoms 5 point severity scale	For LI<1, severity=0.2 LI<3, severity=3.6 LI>3, severity=4.1	Wang et al. 1998
	• Industrial jobs (403) with repetitive lifting • Cross-sectional	Lumbar motion monitor Biomechanical analyses Model includes lift rate, Average twisting velocity, maximum moment, maximum sagital flexion, maximum lateral velocity	OSHA 200 log for low back pain	OR=6.3 for medium versus low risk groups 10.6 for high versus low risk groups	Marras 1995
	• 1988 NHIS US population survey	Self-reported duration of exposure to strenuous lifting, pushing, pulling or repetitive bending, twisting, reaching Considered , age, gender, race, smoking	Self reported low back pain > 1week in last year	OR=1.9 for strenuous lift/push/pull 2.4 for repetitive bend/twist/reach 1.6 for current smoker 1.4 for blue vs. white collar 1.4 for BMI>28 1.2 for height>70” 1.2 for age 35-59 vs. 18-34 1.3	Park et al. 1997

Risk Factor	Industry and Study Type	Method of Exposure Measurement	Disorder Studied	Statistically Significant Risk Estimates	Reference
Moderate to High Hand-Arm Vibration					
Hand arm vibration > 2.5m/sec2 8 hour energy equivalent	• Chain saw operators (65) and controls (31) • Cross-sectional	Observational analysis Vibration measurements No differences between groups on other exposure factors than vibration	Interview and clinical examination Systemic diseases, demographics, Body mass index	Odds ratios for groups with vibration <7.5m/s^2 vs. >7.5 m/s^2 OR=0.9 vs. 3.8 for tension neck syndrome 2.8 vs. 10.7 for cervical neck WMSDs 3.0 vs. 8.5 for epicondylitis 3.6 vs. 39.8 for carpal tunnel syndrome	Bovenzi et al. 1991
	• Forestry workers (222) and controls (195) • Cross-sectional	Workplace assessment questionnaire Considered demographics, smoking, alcohol use	Questionnaire Finger blanching Cold provocation	Lifetime exposure ln (m^{2}s hd) OR=4.1 for <19 4.7 for 19-20 9.4 for 20-21 34.3 for >21.	Bovenzi et al. 1995
	• Heavy engineering company workers (165) exposed to vibration • Cross-sectional	Questionnaire Chipping hammers, pneumatic grinders, caulking hammers. Acceleration levels of tools measured. Exposure times estimated: welders 1.5 hours, fitters 2 hours, dressers 5 hours. Considered demographics, smoking status	Physical examination, staging of neurological and vascular components of hand arm vibration syndrome	Relationship between total hours of exposure and severity of neurological and vascular signs while controlling for age and smoking. Years of exposure is a strong surrogate measure. Chipping hammers have higher acceleration and cause more damage than grinders for the same exposure time.	McGeoch and Gilmour 2000
	• Population based • Case control	Questionnaire, Power tool use validated with observation analysis	Newly diagnosed carpal tunnel syndrome cases at clinic	OR=0.5 for <1 hours (NS) 1.5 for 1-2 hours (NS) 1.6 for >2-5 hours (NS) 3.3 for 6+ hours Body mass index was a significant predictor	Nordstrom 1997

THE RULE IS TECHNOLOGICALLY AND ECONOMICALLY FEASIBLE FOR AFFECTED INDUSTRIES

Summary of small business economic impact study (RCW 19.85)

The department has completed a Small Business Economic Impact Statement (SBEIS). Despite little evidence that the rule will pose an unfair burden on small employers, the department recognizes that small businesses face inherent challenges that might not be fully demonstrated in the analysis. Therefore, the department has chosen to make special allowances to mitigate the potential costs and impacts on small businesses.

Using a combination of information from employer surveys and labor market information, the SBEIS estimated that the average cost per employee would be less than 10 cents per day and the average overall costs per employer less than 0.025 percent of sales. Overall, and in eight of 10 one-digit SIC industry categories examined, average overall costs per employee were found to be lower for small employers than for large employers. Costs as a percent of sales were somewhat higher for small businesses than for large. In spite of a lack of overall evidence that there was a disproportionate cost to small businesses compared to large businesses, the department decided to make special allowances to mitigate potential costs for small businesses:

- The phase-in provides significantly more time for small businesses to comply with the rule. This will allow small businesses to take advantage of methods and controls used by larger employers who need to comply earlier.
- The implementation plan includes substantial efforts by the department to provide assistance for small businesses in preparing for the rule during the phase-in period.
- Employers will have options for analyzing and controlling WMSD hazards. This includes very specific criteria to follow or the choice of using other criteria that may better meet the employers' needs.
- The department's method of assessing penalties for violations of rules allows a very substantial penalty reduction for small employers.

Summary of Cost-benefit analysis (RCW 34.05.325)

L&I has completed a Cost-Benefit Analysis. L&I estimates the full annual direct costs of industrial insurance claims for the types of WMSDs addressed by the rule to be greater than $450 million. The actual total cost is much higher than these measurable direct costs. First, insurance payments do not fully compensate workers for lost time and income. Second, there is evidence that workers make sizable out of pocket payments to treat WMSDs. (Morse et al. 1998) Third, there are other sizable indirect costs associated with WMSDs. These are borne by the employer in the form of higher absenteeism, turnover and replacement training costs as well as lower overall productivity and quality. (Carter and Boquist 1995; Westgaard and Aaras 1984, 1985; Murphy 1992; Amey 1992; Oxenburgh 1991; Davis 1999; Wick and Johnson 1995; Ferris 1992; Burton et al. 1999) Indirect costs are also borne by the employee afflicted with a serious WMSD in the form of reduced long term earning potential and family stability. There is evidence that workers with WMSDs suffer lost earnings long after wage replacement benefits cease (Boden and Galizzi 1999; Reville 1999; Biddle 1998). Indirect employer cost estimates range from 0.5 to 20 times direct costs depending on the method of calculation and the type of injury being studied. (Brody 1990; Heinrich 1959; Andreoni 1986; Hinze 1991; Jack Azar, Xerox comments to OSHA ergonomics rulemaking) L&I's analysis makes the conservative assumption that indirect employer costs are 75 percent of direct costs of WMSDs. L&I estimates the total costs of WMSDs addressed by this rule to be more than $1 billion yearly.

A large amount of costs borne by workers with WMSDs cannot be quantified. These include household economic losses, decreased ability to perform family and social roles, adverse impact on family relationships, depression and loss of self esteem, decreased contribution to community, pain and suffering. While these costs were not included in the formal cost-benefit analysis for this rule, L&I believes that they are large and important and must be a factor in the process of making public policy decisions about ergonomics.

L&I estimates that the ergonomics rule will prevent 40 percent of WMSD injuries and 50 percent of WMSD costs once all the elements of the rule are fully effective. These are average figures and actual reductions will vary by workplace and by industry. The effectiveness of the rule was estimated in two ways. First, literature reporting on the effectiveness of ergonomic interventions was reviewed. Thirty-six studies reported an average injury reduction of 49 percent. Twenty-four studies reported an average lost workday reduction of 65 percent. Second, the literature on exposure-response relationships was reviewed (Tables 7 and 8). Differences in relative risk at different levels of exposure were noted. The percent reduction in probability of injury was estimated for situations when exposure was reduced from hazard levels to caution zone levels or low exposure levels.

The estimated annual cost for compliance is $80.4 million. The estimated annual social benefit from the rule is $340.7 million. The benefit-cost ratio is 4.24, indicating that the estimated social benefits substantially outweigh the costs. Interpreted another way, this means that there is a 424 percent return on the investment toward reducing WMSDs. The benefit-cost ratios range from 1.55 for agriculture and forestry to 7.03 for non-durable manufacturing. L&I calculated upper and lower bound estimates on the costs and benefits. Even for the combination of low estimated benefit and high estimated cost the benefit-cost ratio was 3.13. The industry specific benefit-cost ratio for this worst case scenario of low benefits and high costs ranged from 1.14 for agriculture to 5.20 for non-durable manufacturing.

The L&I analysis is consistent with reports from various existing ergonomics programs. For example: "We have conducted a cost-benefit analysis of our ergonomic activities at one major manufacturing plant. Over the past 8 years, this plant has reduced its ergonomic injuries/illnesses and related direct cost by approximately 50% and 75% respectively, for a cumulative savings of $3.6M since 1992. Utilizing a 2X multiplier to account for related indirect costs yields a cumulative savings of $7.2M on ergonomics staff and equipment modifications/purchases. It is apparent that this investment yielded positive results." (Jack Azar, Xerox comments to OSHA ergonomics rulemaking 2/18/2000)

Summary of evidence for technological feasibility

L&I has made the determination that the ergonomics rule is technologically feasible, using the following analytic framework:

- An employer's technological capacity to comply with the rule depends on its ability to control employee exposures to the risk factors regulated by the rule. L&I therefore focused its feasibility inquiry on the technology currently available and in use to reduce these WMSD hazards as well as industry's demonstrated ability to adapt the technology to individual employer circumstances and the potential for technological innovation.
- For the risks regulated by the rule, there is considerable evidence in the record that the technology to control risk factors is in general use and widely available. Moreover, there was little testimony or written commentary arguing that technological solutions for WMSD hazards do not exist, cannot be conceived or cannot be developed. In fact, the comments on the rule provide considerable documentation that solutions for WMSD hazards exist and can be implemented.
- While effective control technology is already widespread, it might be necessary to adapt modifications to various situations. However, even where innovation is necessary, there is very little need for new technology to comply with the rule. Adaptation of existing technology should permit employers to achieve compliance. L&I's experience to date and evidence in the record indicates a large, untapped capacity for innovation. L&I concluded that the technological resources exist to allow this innovative capacity to flourish. Moreover, the rule will create a strong market for technologies that reduce ergonomic risk factors.
- Experience in adapting technology to reduce WMSD hazards has shown that employers, particularly working together with employees, have been able to devise practical and plain sense solutions. Joint labor-management ergonomic programs in the automobile and other industries have reported numerous examples.[44]
- The ability to adopt or adapt technology is enhanced if employers have adequate time to incorporate the necessary improvements into their businesses. L&I has provided a generous timeframe for compliance with this rule, easing an employer's ability to adapt to its requirements.
- Finally, the rule makes allowance for those individual employers who find that a generally feasible hazard control method is not feasible in a particular workplace because of unique and specific circumstances.

Using this framework, L&I undertook a five step analysis based on evidence in the record and the experience and expertise of agency professional staff:

- First, L&I identified a set of core ergonomic principles (Table 9) and core control methods (Table 10) applicable to the risk factors governed by the rule.

[44] Well-developed examples of joint labor-management ergonomics programs can be found in the automobile industry where the United Automobile Workers International Union (UAW) and the major automobile manufacturers have had programs in place since the 1980s. Materials describing these programs include: Ergonomics Awareness Reference Guide, UAW-GM Human Resource Center, 1991; The UAW-Ford Ergonomics Action Guide, UAW-Ford National Joint Committee on Health and Safety, 1996; Partners in Free Motion, UAW-Chrysler National Training Center, 1991

- Second, L&I determined that these ergonomic principles have been successfully applied across a wide variety of industries and types of work. Selected examples illustrating these control methods are in Table 11.
- Third, five professional ergonomists reviewed work processes and occupational activities within industry groups (classified by 2 digit and 3 digit SIC codes) to determine where there were similarities and differences in work processes, jobs and risk factors. Based on this evaluation, L&I identified groups of industries for which similar control methods are applicable. Selected examples from this industry roll-up are in Table 12.
- Fourth, L&I determined that the application of core ergonomic principles and methods has been sufficiently widespread and successful in each of the industry groups to expect that adoption throughout each industry group is feasible. L&I considered the ease with which technology has been adapted to its current uses and estimated whether further adaptation of such technology within industry groups seemed likely. In deciding whether adaptation of technology could be achieved, L&I considered the compliance timeframes in which such adaptation would be required.
- Fifth, L&I considered the evidence as a whole and determined that the rule is technologically feasible in all industry groups covered.

Table 9 Core Ergonomic Principles

1. Adapt the work space and the work equipment to take into account the dimensions of the operator and the kind of work being performed with preferred body postures, namely trunk erect, body weight appropriately supported, elbows at the side of the body and forearms approximately horizontal.
2. Provide sufficient space for body movements, especially the head, arms, hands, legs and feet.
3. Provide variety in tasks and movements to avoid static muscle tension caused by postural constraints
4. Design work to allow machinery to do or assist with highly repetitive tasks; leave more variable tasks to human operators
5. Put controls within functional reach. Grips and handles need to suit the functional anatomy of the hand.
6. Keep loads close to the body and handle with neutral postures
7. Keep strength demands compatible with the physical capacities of the worker.
8. Use mechanical assistance if strength demands exceed the capacity of muscle groups.
9. Use larger muscle groups for higher forces, smaller muscle groups for precision work.
10. Do not combine requirements for great accuracy and strength on the same job at the same time.
11. Avoid extreme postures when exerting high force.
12. Design tasks to permit gripping with the fingers and the palm instead of pinching
13. Reduce segmental vibration hazards from using power tools by reducing the tool's vibration intensity, reducing exposure time, or isolating the individual from the vibration
14. Provide adjustable equipment, workstations, tools
Adapted from International Standards Organization 6385: Ergonomic principles in the design of work systems, 1981; Salvendy 1994; Sanders and McCormick 1987; Ergonomic Design for People at Work by Eastman Kodak, Rodgers et al. 1986

Table 10 Core Ergonomic Control Methods - Examples

Hazard	Ergonomic Control Methods
AWKWARD POSTURES	
Working with hand(s) above the head or the elbow(s) above the shoulder(s), more than 4 hours total per day	• Raise the worker up with elevated work platforms or ladders. • Make tools longer with articulating arms or extension handles. • Bring the work down and tilt it on its side for better access • Provide adjustability where possible for multiple users • Design reach distance for the shortest worker • Provide arm supports • Use sloping platforms with overhead conveyers to adjust for variable worker heights
Repetitively raising the hand(s) above the head or the elbow(s) above the shoulder(s) more than once per minute, more than 4 hours total per day	• Limit overhead storage to infrequently used items. • Raise the worker up with elevated work platforms or ladders. • Make tools longer with articulating arms or extension handles. • Bring the work down and tilt it on its side for better access. • Provide adjustability where possible for multiple users • Design reach distance for the shortest worker
Working with the neck bent more than 45°(without support or the ability to vary posture), more than 4 hours total per day	• Raise and tilt objects being viewed to keep neck more upright. • Use magnifiers when working on objects with the hands in order to keep the arms and shoulders down. • Support the head with a chin/forehead cradle. • Use monitor arms or stackers to raise up monitors • Use video or mirror systems to view objects or locations that are difficult to see (dental/medical/surgical tasks, fork trucks)
Working with the back bent forward (without support or the ability to vary posture) more than 30 degrees for more than 4 hours per day, or more than 45° for more than 2 hours per day	• Raise and tilt the work to provide better access. • Use a sit/stand stool to lower the worker. • Make tools longer with articulating arms or extension handles. • Alternate between bending, sitting, kneeling and squatting. • Use a chest pad to support the weight of the upper body. • Locate objects well within arms' reach • Use body carts for ground level work

Table 10 Core Ergonomic Control Methods - Examples

Hazard	Ergonomic Control Methods
Squatting more than 4 hours total per day	• Raise the work to provide better access. • Make tools longer with articulating arms or extension handles. • Alternate between bending, sitting, kneeling and squatting. • Use body carts for ground level work • Use short portable stools for ground level work
Kneeling more than 4 hours total per day	• Wear knee pads. • Raise the work to provide better access. • Make tools longer with articulating arms or extension handles. • Alternate between bending, sitting, kneeling and squatting.

HIGH HAND FORCE	
Pinching an unsupported object(s) weighing 2 or more lbs. per hand or pinching with a force of 4 or more pounds per hand, combined with highly repetitive motions for more than 3 hours total per day	• Redesign hand-tool interface for use of a power grip. • Reduce weight of tool or object. • Use clamps or vices to eliminate forceful pressing or pinches • Use fasteners requiring minimal pinch force (e.g. plastic rather than metal) • Use fasteners that can be inserted by tool
Pinching an unsupported object(s) weighing 2 or more lbs. per hand or pinching with a force of 4 or more pounds per hand, combined with wrists bent in flexion 30^{o} or more or in extension 45^{o} or more for more than 3 hours total per day	• Redesign hand-tool interface for use of a power grip. • Reduce hand-object interface to reduce slipperiness • Reduce weight of tool or object. • Change tool, work surface orientation, or worker location to reduce bent wrist postures.
Pinching an unsupported object(s) weighing 2 or more lbs. per hand or pinching with a force of 4 or more pounds per hand for more than 4 hours total per day	• Redesign hand-tool interface for use of a power grip. • Reduce weight of tool or object. • Rotate jobs between workers. • Use clamps or vices to eliminate forceful pressing or pinches • Use fasteners requiring minimal pinch force (e.g. plastic rather than metal) • Use fasteners that can be inserted by tool

Table 10 Core Ergonomic Control Methods - Examples

Hazard	Ergonomic Control Methods
Gripping an unsupported object(s) weighing 10 or more lbs. per hand or gripping with a force of 10 or more pounds per hand, combined with highly repetitive motions for more than 3 hours total per day	• Reduce weight of tool or object. • Use balancers, adjustable fixtures, articulating arms to hold handled items or minimize weight held in the hand • Use two hands rather than one • Alternate between hands • Sharpen cutting tools to reduce force requirements during use • Rotate between tasks
Gripping an unsupported object(s) weighing 10 or more lbs. per hand or gripping with a force of 10 or more pounds per hand, combined with wrists bent in flexion 30^{o} or more or in extension 45^{o} or more or in ulnar deviation 30^{o} or more for more than 3 hours total per day	• Reduce weight of tool or object. • Change tool, work surface orientation, or worker location to reduce bent wrist postures. • Use balancers, adjustable fixtures, articulating arms to hold handled items or minimize weight held in the hand • Use two hands rather than one • Alternate between hands • Sharpen cutting tools to reduce force requirements during use
Gripping an unsupported object(s) weighing 10 or more lbs. per hand or gripping with a force of 10 or more pounds per hand, more than 4 hours total per day	• Reduce weight of tool or object. • Rotate jobs between workers. • Use balancers, adjustable fixtures, articulating arms to hold handled items or minimize weight held in the hand • Use two hands rather than one • Alternate between hands • Sharpen cutting tools to reduce force requirements during use • Preventive maintenance of tools to reduce high hand forces • Use bench mounted adapters to provide more leverage

Table 10 Core Ergonomic Control Methods - Examples

Hazard	Ergonomic Control Methods
HIGHLY REPETITIVE MOTIONS	
Using the same motion with little or no variation every few seconds (excluding keying activities) more than 6 hours total per day	• Rotate jobs with other workers, varying the types of motion • Use job enlargement, increase the number of tasks performed by the worker, varying the types of movement • Reduced the speed of the motions if possible • Use mechanical assists • Use multifunction tools
Using the same motion with little or no variation every few seconds (excluding keying activities) combined with wrists bent in flexion 30^o or more or in extension 45^o or more or in ulnar deviation 30^o or more, and high, forceful exertions with the hand(s), more than 2 hours total per day	• Re-orient or move objects into positions where bent wrists are eliminated • Rotate jobs with other workers, varying the types of motion • Use tools (with power grip) if exertions are required • Provide jig/vice to hold parts reducing forceful grasping and allowing the use of two hands • Use mechanical assists • Use multifunction tools
Intensive keying for more than 7 hours total per day, or combined with awkward postures for more than 4 hours total per day	• Enlarge the job to include tasks other than keying • Provide equipment to reduce awkward postures such as wrist rests, arm rests, adjustable keyboard shelves • Rearrange workstation to eliminate awkward postures e.g. raise monitor, lower keyboard, bring mouse closer to keyboard • Utilize voice-recognition software • Utilize software macros that automate repetitive keystrokes • Schedule breaks

REPEATED IMPACT	
Using the hand (heel/base of palm) as a hammer more than once per minute more than 2 hours total per day	• Use rubber mallets, bean bags, or other padded tools to strike with instead of the palm. • Press objects into place using levers, or hydraulic or pneumatic tools. • Redesign assembly processes to avoid the need to pound parts in by hand. • Use viscoeleastic padded palm pads to reduce impact • Cover sharp or hard objects with pads • Use different types of palm button guards such as light sensors for manual activation of equipment
Using the knee as a hammer more than once per minute more than 2 hours total per day	• Use tools that don't require knee kicks, such as power stretchers for carpet laying, or long handled mallets. • Press objects into place using levers, or hydraulic or pneumatic tools. • Relocate knee switches so that the thigh or the foot presses them. • Redesign processes to avoid the need to pound parts in by knee

Table 10 Core Ergonomic Control Methods - Examples

Hazard	Ergonomic Control Methods
HEAVY, FREQUENT or AWKWARD LIFTING	
Heavy lifting	• Reduce weight of load • Increase weight of load so that it requires mechanical assist • Reduce the capacity of the container • Use slides, gravity chutes to eliminate lifting • Use mechanical assist such as overhead hoist, manipulator, vacuum lift, pneumatic balancer, forklift • Use telescoping extendible conveyors with powered belts that reach deep into trailers • Reduce the horizontal distance of the load away from the body by reducing the size of the packaging • Reduce the horizontal distance of the load away from the body by removing barriers, obstacles that make access to the object difficult • Team lift the object with two or more workers • Improve layout of work process so the need to move materials is minimized • Provide handholds which increase lifting capability up to 15%
Frequent lifting	• Use mechanical assist such as overhead hoist, manipulator, vacuum lift, pneumatic balancer, forklift • Reorganize work method to eliminate repeated handling of the same object • Rotate workers to jobs with light or no manual handling • Use slides, gravity chutes to eliminate lifting • Use mobile storage racks to avoid unnecessary loading and unloading
Awkward lifting	• Redesign workstation layout to eliminate trunk twisting by locating objects within arm's reach • Design workstation with adjustable heights to eliminate bent forward posture when lifting • Eliminate the use of deep shelves that require a worker to bend and reach for objects. • Store objects at 30" off the floor • Provide sturdy walk-up ladder with handrails to access stored parts on high shelves/racks. • Provide rigid containers to better control the load

Table 10 Core Ergonomic Control Methods - Examples

Hazard	Ergonomic Control Methods
HAND-ARM VIBRATION	
Segmental vibration	• Select power tools with lower vibration emission levels • Provide regular maintenance to eliminate vibrations caused by imbalanced mechanical parts e.g. grinding wheels • Increased tool weight could reduce vibration transmitted to the hands, though cautions should be taken not to introduce other risk factors • Using balancers, isolators, damping materials, articulating arms, vertical suspension, and counter weighting to reduce grip requirements and provide an alternative transmission route for vibrational energy • Use battery operated rather than air powered tools where possible • Isolate vibration between source and hand by providing handles with a well designed mass-spring system or anti-vibration gloves • Tools should have a high power to weight ratio, have low torque with a cutoff rather than a slip-clutch mechanism and have handles with a non-slip surface to reduce the need to grip tightly. • Reduce vibration exposure duration
Note: This table provides examples of how the core ergonomics principles can be used to reduce exposure to musculoskeletal hazards. These examples are a selection from the rulemaking file.	

Table 11 Selected Examples of Ergonomic Applications

Source	Workplace Description	Type of Intervention	Results
Schutte & Schuder 1997	Auto assembly	Sloping platform with overhead conveyor to adjust for variable worker height	Decreased awkward posture, decreased strain
Westgaard & Aaras 1985 Aaras 1994	Electronics	Tilt tables in cable forming	Reduced awkward postures, reduced sick leave
Newspaper Association of America 1996 Rosecrance 2000	Newspapers	Tilt table in lay-up	Reduced neck flexion
Bao 2000	Fastener distribution center	Use forktruck to position pallets with heavy boxes at waist height	Eliminate awkward heavy lifting
Burdorf and Duuren 1993	Planing machine operators	Raising platforms, roller paths and tables	Reduce heavy lifting in awkward postures
Benson 1987	Fabricated metal products	Install conveyor to deliver metal bars to workstations for packaging	Reduced frequent manual handling
Hagen 1993	Logging	Lengthen lifting hooks	Reduced awkward back postures
Meyer 1999	Ground crop harvest	Body carts	Reduced bending, twisting, squatting, kneeling duration
Chang et al. 1999	Landscaping, gardening	Replace wood handles of rakes, shovels etc. with hollow fiberglass handles	Reduce hand force, weight of load
Dempsey et al. 2000	Ice cream stores	Sharpen scoopers every month Have freezer temperatures no lower than $-14^{o}C$	Reduce hand force requirements, increase efficiency
Marklin and Wilzbacher	Electric utility warehouses	Move 80 pound capacitors stored in crates on floor to stacked pallets (mid thigh height).	Reduced heavy lifting in awkward postures (NIOSH

Table 11 Selected Examples of Ergonomic Applications

Source	Workplace Description	Type of Intervention	Results
1999		Replaced heavy oak board gates with light pine boards for removing equipment off trucks. Used height adjustable lift table to move meters from rack to test. Picking parts, palletizing and wrapping with cellophane replaced with semi-automatic machine for wrapping	Lifting Equation Index reduced). Repetitive bending/lifting of meters from rack eliminated. Reduced awkward reach, bending, force requirements
Moore and Garg 1998	Meatpacking	Replaced manual deboning with deboning machine, modified tools, vacuum carrying devices, developed sharpeners and straighteners, automated loin pulling	Improved quality of meat, yield increased, decrease in lost time incidence rate, , decrease in workers compensation costs
Brisson et al. 1999	VDT workers	Ergonomic training program on workstation changes to reduce awkward postures	Reduced awkward postures, MSDs decreased from 29% to 13% in test group, no change in control group
Owen and Garg 1994	Nursing homes	Replace manual lifting of patient onto scales with ramp scale and hoist with digital scale	Awkward postures and high forces reduced, patient comfort and security ratings increased
Rooney and Morency 1992, 1993	Apparel sewing	Adjustable workstations, jigs & fixtures to hold work pieces; partial automation; designed and fabricated own tools; redesigned machinery	In 1990, 373 modifications to 214 workstations: reduced force in 172, reduced repetitive angles in 141, reduced awkward postures in 60.
Jones 1997	Poultry processing	Automated thigh popper, skin remover machines, adjustable stands, pneumatic tub dumper, improved sharpening equipment, job rotation, micro-breaks	Reduced awkward postures, high hand forces, static positions
Aaras, Ro and Thoresen 1999	VDT operators	Improved mouse design	Eliminated pinching, eliminated awkward forearm and wrist posture
Garg 1999	Hospital & nursing homes	Implemented zero-lift with mechanical transfer assists, training,	Reduced awkward postures, reduced heavy lifting, reduced

Table 11 Selected Examples of Ergonomic Applications

Source	Workplace Description	Type of Intervention	Results
			high hand forces
Johansson et al. 1998	Grocery checkout	Place weight scales under the conveyer belt in front of the cashier versus to the side	Scale location under the conveyor reduced awkward postures.
Food Marketing Institute 1995	Food Distribution Centers	Look for alternative suppliers that can provide items in lighter units, Change pick routing systems to allow selectors to build easier load, create orders below 77 inches	Reduce heavy lifting, Reduce awkward lifting
Van Dieen et al. 1997	Harvesting radishes	Alternate between using radish harvest chair and kneeling	Reduce kneeling, Reduce back bending but may increase twisting
Meyers et al. 1999	Wine grape harvesting	Reduce tub size for carrying cut grapes	Reduced loads from average of 57 pounds to 47 pounds
Janowitz 1998	Ornamental Nurseries	Use T handle to grip 1 gallon and 5 gallon pots with power grip	Reduce high hand force, Reduce back bending
Van der Molen 1998	Gypsum bricklayers	Mechanical transport devices –small hydraulic crane with remote control equipment, trolley to carry, lift bricks in houses. Reduce mass but not size of the bricks	Reduce heavy, awkward, frequent lifting

Note: Examples have been drawn from a wide variety of sources including peer reviewed scientific literature, trade journals, presentations, websites, government agencies and others. These examples are a selection from a more complete table in the rulemaking file. Many of the studies and reports in this table and the full technical feasibility file demonstrate reductions in WMSD incidence or severity as well as reduction in exposure to risk factors.

Table 12 Industry Roll-up Examples

Industry Description	Possible Caution/Hazard Factors	Possible Solutions
SIC 176 Roofing, Siding and Sheet Metal Work (could not be combined with other SICs) Approximately 20% of jobs in these classifications are involved in white collar work such as managerial, administrative and sales positions. The rest of the jobs are comprised largely by roofers, at about 50%, with 10% carpenters and 10% laborers.	• Working with the neck or back bent more than 30 degrees. • Squatting or kneeling • Highly repetitive motion • Heavy or awkward lifting (material handling) • High vibration levels from power tools • High grip and pinch force	• Ergonomics awareness training for all workers in Caution Zone jobs. • Use low-vibration hand tools and possibly vibration-dampening material for all jobs involving frequent use of powered hand tools. • Use lighter-weight nail guns and other tools to reduce hand force requirements. • Use drill extensions and other aides where applicable to reduce duration of awkward postures. • Alternate equally between squatting and kneeling during an eight-hour day if working with the hands near foot level. • Choose the tool or alter tool handles to appropriately match them with the task. • Mechanize or equipment-assist any manual activities involving heavy or frequent lifting such as transferring large amounts of material to a location on or within a work site. • Employ team lifting where other interventions are not possible. • Rotate workers between tasks with different risk factor levels and postures when possible. • Use powered tools for installing fasteners where tools exist without high torque, high vibration, awkward handles or excessive weight. • Pre-plan activities to limit carrying and awkward postures. Pre-construct structural components at a more comfortable height/geometry when possible. • Limit exposure to lifting a mop with roof material by attaching a mop-pivot on the

Table 12 Industry Roll-up Examples

Industry Description	Possible Caution/Hazard Factors	Possible Solutions
		bucket, by decreasing the size of the mop head or other intervention if possible. • If lighter rolls of felt are lifting with one person, pivot the roll over the knee to increase the effective lifting height. • Raise the height of material pallets where advantageous by using inexpensive stands or empty pallets
SIC 261-269 Pulp and paper or the related manufacturers (including pulp mills, paper mills, paperboard mills, paperboard containers and boxes, and other miscellaneous converted paper products) About 16-43% of the jobs in these classifications are involved in office jobs such as managerial, administrative and sales job functions. Production jobs usually consist of about 56-83% of the workforce in these classifications. The production jobs are often involved in processes such as converting processes, loading or offloading materials, manual shipping, receiving, or material handling operations, molding, packaging, paper cutting, shipping, receiving, or material handling operations, storage or handling of pulpwood, warehouse operations etc. There are some unique processes in paperboard containers and boxes and miscellaneous converted paper products, such as box or container making, and bag making operations. Risk factors and solutions related office and service jobs are discussed under other relevant job categories.	Caution Zone: ▪ Heavy, frequent or awkward lifting: ▪ Awkward postures: Working with the neck or back bent more than 30^o ▪ Using hand tools that typically have high vibration levels ▪ Heavy, frequent or awkward lifting depending on the work postures when performing certain maintenance jobs. ▪ At certain workplaces, these limits could be further reduced by the frequency of lifting, and the presence of twisting postures. ▪ Awkward postures: Working with the neck bent 45 degree ▪ . Working with the back bent forward more than 30 degree without added support for more than 4 hours total per workday.	▪ Ergonomics awareness training for all workers in Caution Zone jobs. ▪ Using lift assist devices when heavy objects need to be lifted, rather than manually lifting heavy objects. ▪ Properly position objects to avoid lifting heavy objects at awkward postures. ▪ Properly design the workstations and work procedures, so that the awkward postures will not be required or will be minimized. ▪ Develop skills of dealing with emergency situations such as product jam-ups, to avoid heavy lifting situations.
SIC 371-379 Vehicle and aircraft related manufacturers (including manufacturers of motor vehicles and equipment, aircraft and	▪ Heavy, frequent or awkward lifting ▪ Awkward postures: Working with the neck or back bent more than 30 degrees without	▪ Ergonomics awareness training for all workers in Caution Zone jobs. ▪ Using lift assist devices when heavy objects

Table 12 Industry Roll-up Examples

Industry Description	Possible Caution/Hazard Factors	Possible Solutions
parts, ship and boat building and repairing, railroad equipment, motorcycles, bicycles, and parts, guided missiles, space vehicles, and parts, and other miscellaneous transportation equipment) About 17 to 69% of the jobs in these classifications are involved in office jobs such as managerial, administrative and sales job functions. Production jobs usually consist of about 31 to 83% of the workforce in these classifications. There are up to 1% of the workforce involved in the service jobs. The production jobs are often involved in the processes such as assembly or fabrication operations, buffing, polishing, abrading and grinding, conventional metal machining, finishing, coating or painting, forming or bending, heavy assembly using automated equipment, loading or offloading, manual shipping, receiving, or material handling operations, warehouse operations, welding, welding, metal casting, non-conventional metal machining (for aircraft and parts) etc. Ship and boat building and repairing manufacturers also have carpentry processes. Risk factors and solutions related office and service jobs will be discussed under other relevant job categories. Risk factors and solutions related to carpentry jobs can be found in the jobs of construction industries. Only production job categories will be discussed here.	support ▪ High hand force ▪ Highly repetitive motion: ▪ Moderate to high vibration: Using hand tools that typically have high vibration levels for more than 30 minutes per day. ▪ With bent wrists in more than 30 degrees or in extension of more than 45 degrees or ulnar deviation of greater than 30 degrees, and high forceful hand exertions, the duration limit is reduced to 2 hours per workday.	need to be lifted, rather than manually lifting heavy objects. ▪ Properly position objects to avoid lifting heavy objects at awkward postures. ▪ Properly design the workstations and work procedures, so that the awkward postures will not be required or will be minimized. ▪ Rotating between different jobs with different exposure patterns. ▪ Reduce high hand force by using proper power tools or change production procedures. ▪ Modify the work procedures causing the increased frequency of repetitive motions, or rotating operators between the highly repetitive motion jobs and less repetitive motion jobs. ▪ Select power hand-held tools with lower declared vibration values when the tools need to be frequently used. ▪ Limit the duration of holding activated vibration tools so that the 8-hour equivalent vibration level is lower or equal the recommended limit. ▪ Properly maintain power hand-held tools to reduce excessive vibrations due to poor maintenance.
SIC 441-449 Water transportation of freight, marine cargo handling, towing and tugboat services	• Heavy, Frequent or Awkward Lifting: Exceeding acceptable lifting limits. (material handling)	• Use lifting-assist devices and store materials in a location and height that minimized physical impact.

Table 12 Industry Roll-up Examples

Industry Description	Possible Caution/Hazard Factors	Possible Solutions
Between 25%-30% of jobs in these classifications are involved in white collar work such as managerial, administrative and sales positions. Between 10%-15% of jobs involve manual material handling. Between 10%-15% of jobs involve operating material handling equipment. Between 10%-15% of jobs involve production supervisors. Between 10%-15% of jobs involve ship operators. Between 5%-10% of jobs involve mechanics/maintenance.	Mechanics/maintenance only • High Hand Force: Holding and supporting a 10+ pound object with a power grip more than 3 hours total per day in awkward postures. Holding and supporting a 2+ pound object with a pinch grip more than 3 hours total per day in awkward postures. (maintenance activities) • High Vibration: Using hand tools that typically have high vibration levels above acceptable limits. (maintenance activities)	• Employ team lifting where other interventions are not possible. • Pre-plan activities to limit carrying and awkward postures. Pre-construct structural components at a more comfortable height/geometry when possible. • Mechanize or equipment-assist any manual activities involving heavy or frequent lifting such as transferring large amounts of material to a location on or within a work site. • Provide sufficient room to permit workers to move freely and avoid awkward positions. • Substitute power tools for manual tools whenever possible • Use torque reaction bars and mounted hut holding devices to control for torque reaction force in power tools • Use balancers, articulating arms, and counter weighting to reduce grip requirements • Enact a proactive maintenance program that replaces worn parts of equipment or tools as quickly as possible to limit vibration due to malfunction • Use low-vibration hand tools and possibly vibration-dampening material for all jobs involving frequent use of powered hand tools.
SIC 821-829 Educational Services Between 85%-95% of jobs in these classifications (elementary and secondary schools, colleges and universities, libraries, and other schools) are involved in white collar work such as managerial, professional and sales positions, with the exception being vocational schools, where 40%-55% of jobs are white collar . The rest of the jobs in these industries involve vocational instructors, teachers, teaching assistants, professors, laboratory worker,	• Awkward postures: Bending the neck or back more than 30 degrees without support and without the ability to vary posture for more than 4 hours per day, or more than 45 degrees more than 2 hours per day. • Highly repetitive motion: Repetitive motions in combination with awkward wrist postures and high hand forces for more than 2 hours per day; or intensive keying for more than 6 hours per day; or intensive keying in awkward postures for more than 4 hours per day	• Ergonomics awareness training for all workers in Caution Zone jobs. • Computer workstation adjustment to reduce awkward postures. • Use of automatic pipettors, automated cell counters, other equipment to reduce repetitive motions and awkward postures in labs • Use of adjustable fixtures, adjustable microscope stands and eyepieces to reduce awkward postures in labs • Improved shelving and carts in libraries to

Table 12 Industry Roll-up Examples

Industry Description	Possible Caution/Hazard Factors	Possible Solutions
clerical worker, secretaries, and support functions such as maintenance and repair, janitorial, groundskeeping, and security services.	• Heavy, Frequent or Awkward Lifting: Lifting objects in excess of lifting limits detailed in the Appendix B calculation	reduce awkward postures • Padded handles on hand tools to reduce grip forces. • Angled hand tools to improve wrist postures. • Use of padded body supports when bending at the back. • Use of power tools to reduce repetitive motions with hand tools. • Use of low-vibration tools, add on vibration damping, anti-vibration gloves (as appropriate), tool support stands and counterbalance handles to reduce vibration exposure and tool weight per hand. • Use of handtrucks, carts to substitute for lifting. • Size limits on paper files to reduce grip forces • Weight limits on storage boxes, supply purchases to reduce weight lifted • Improved storage of supplies, boxes to reduce awkward postures when lifting.
SIC 801-809 Health Services Between 10%-50% of jobs in these classifications are involved in white collar work such as managerial, professional and sales positions. The lowest percentage of white collar workers is in home health care (10%), followed by nursing homes (15%), hospitals (25%), dentists' offices and medical/dental laboratories (30%), physicians', osteopaths' and other practitioners' offices (40-45%). The highest percentages of white collar workers are in health and allied services (50%). The rest of the jobs in these industries involve, patient care by doctors, RNs and LPNs, nursing assistants, orderlies, dentists, dental hygienists, physical therapists, opticians, ophthalmologists; laboratory work by radiological, medical and dental	• Awkward postures: Bending the neck or back more than 30 degrees without support and without the ability to vary posture for more than 4 hours per day, or more than 45 degrees more than 2 hours per day. • High hand forces: Holding objects weighing more than 10 lbs. per hand with a power grip, or use of a power grip with more than 10 lbs. of force for more than 4 hours per day, or combined with awkward postures for more than 3 hours per day • Highly repetitive motion • Heavy, Frequent or Awkward Lifting • Moderate to High Vibration: Using vibrating tools in excess of the vibration hazard limit curve in Appendix B.	• Ergonomics awareness training for all workers in Caution Zone jobs. • Use of patient transfer devices, zero lifting policies to reduce heavy, awkward lifting • Proper patient positioning in adjustable exam tables, dental chairs to avoid awkward postures • Use of ultrasonic dental equipment to reduce repetitive motions, pinch grips, awkward postures among dental hygienists • Use of magnifying devices and improved lighting to avoid bending at the back and neck during dental/surgical work • Computer workstation adjustment to reduce awkward postures. • Use of automatic pipettors, automated cell counters, other equipment to reduce repetitive

Table 12 Industry Roll-up Examples

Industry Description	Possible Caution/Hazard Factors	Possible Solutions
technicians; computer work by billing clerks, transcriptionists; and support functions such as carpenters and other trades involved in construction and repair work, mechanics, groundskeepers, janitorial and housekeeping, maintenance, food service, counter clerks and cashiers. NOTE: The largest impact is expected with hospitals, nursing homes, home health care, dentists, and medical and dental labs, with a slightly lower impact on doctors' and osteopaths' offices, and for health and allied services.		motions and awkward postures in labs • Use of adjustable fixtures, adjustable microscope stands and eyepieces to reduce awkward postures in labs • Padded handles on hand tools to reduce grip forces. • Angled hand tools to reduce awkward wrist postures. • Using padded body supports for back bending • Use of power tools to reduce repetitive motions with hand tools. • Use of low-vibration tools, add on vibration damping, anti-vibration gloves (as appropriate), tool support stands and counterbalance handles to reduce vibration exposure and tool weight per hand. • Use of handtrucks, carts to substitute for lifting. • Improved storage of parts, supplies to reduce awkward postures when lifting.
Maintenance Activities (Building and Equipment) This is a general activity performed by small percentages of workers in various SIC codes.	• Awkward Postures: Working with the neck or back bent more than 30 degrees without support. • High Hand Force: (nail guns, tools and fasteners) • Heavy or Awkward Lifting: Lifting objects weighing more than 75 pounds once per day or 55 or more pounds more than 10 times per day. (material handling) • High Hand Force: Holding and supporting a 10+ pound object with a power grip more than 3 hours total per day in awkward postures. Holding and supporting a 2+ pound object with a pinch grip more than 3 hours total per day in awkward postures. (heavier hand tools and material) • Highly Repetitive Motions: (constructing)	• Ergonomics awareness training for all workers in Caution Zone jobs. • Use lifting-assist devices and store materials in a location and height that minimized physical impact. • Employ team lifting where other interventions are not possible. • Rotate between tasks with different risk factor levels when possible. • Use low-vibration hand tools and possibly vibration-dampening material for all jobs involving frequent use of powered hand tools. • Choose the tool or alter tool handles to appropriately match them with the task. • Use drill extensions, plasterboard lifts and other aides where possible to reduce the duration of awkward postures.

Table 12 Industry Roll-up Examples

Industry Description	Possible Caution/Hazard Factors	Possible Solutions
	• Heavy, Frequent or Awkward Lifting: (material handling) • High Vibration: Using hand tools that typically have high vibration levels above acceptable limits.	• Pre-plan activities to limit carrying and awkward postures. Pre-construct structural components at a more comfortable height/geometry when possible. • Mechanize or equipment-assist any manual activities involving heavy or frequent lifting such as transferring large amounts of material to a location on or within a work site.
Note: These examples are a selection from a more complete table in the rulemaking file.		